DOE/SF/76026--T29

03-824/26 8-3 Ltr dated 5/19/78

Rockwell International
Atomics International Division

SUPPORTING DOCUMENT

MASTER

NUMBER	N707TR830014
REV LTR/CHG NO.	SEE SUMMARY OF CHG
PROGRAM TITLE	LMFBR Technology
DOCUMENT TYPE	Test Report
KEY NOUNS	Sodium, Wetting Carryover
DOCUMENT TITLE	Test Report: Chain-Hoist Sodium Carryover
ORIGINAL ISSUE DATE	
GO NO.	09278
S/A NO.	32000
PAGE 1 OF	45
TOTAL PAGES	45
REL. DATE	5-12-78

PREPARED BY/DATE	DEPT	MAIL ADDR
P. Horton Philip H. Horton	731	T006
R. M. Oliva R M Oliva 5/10/78		

IR&D PROGRAM? YES ☐ NO ☐ IF YES, ENTER TPA NO. ____

APPROVALS	DATE
O. P. Steele III Oliver P. Steele	5/10/78
L. Baurmash L Baurmash	5/11/78

SECURITY CLASSIFICATION

(CHECK ONE BOX ONLY)	DOE	DOD
UNCL	☒	☐
CONF.	☐	☐
SECRET	☐	☐

(CHECK ONE BOX ONLY)
RESTRICTED DATA ☐
DEFENSE INFO. ☐

AUTHORIZED CLASSIFIER | DATE

DISTRIBUTION

*	NAME	MAIL ADDR
*	Baurmash, L.(6)	LB04
*	Foster, K.	LB15
*	Horton, P.	T006
	Jones, C. E.	LB15
*	Oliva, R.	T005
	Page, J.	LB03
*	Steele,O.P.III	T006
*	J. Mitchell	LB15

ABSTRACT

Tests were conducted to determine the mechanism of sodium carryover at 400°F on the EVTM chain hoist system. Tests were conducted in both the EVTM environmental chamber and in controlled atmosphere glove boxes on a series of test coupons with pre-conditioned surfaces.

In all cases, tin plated coupons wet almost immediately upon immersion in 400°F sodium. No other metals (mild steel, stainless steel, chrome plated steel) wet after immersion for up to 2000 hrs. Cycling the metals in and out of 400°F sodium resulted in "apparent" wetting in the presence of a moisture containing (25-50 ppm) atmosphere with low (<2ppm) oxygen levels. High O_2 (20-100 ppm) levels with low (<2 ppm) moisture levels did not cause sodium adherence. The adherent sodium did not appear to actually wet the metal as it showed a strong tendency to "bead up" after prolonged exposure to an inert gas atmosphere.

RESERVED FOR PROPRIETARY/LEGAL NOTICES

THIS REPORT MAY NOT BE PUBLISHED WITHOUT THE APPROVAL OF THE PATENT BRANCH, ERDA

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

9

* COMPLETE DOCUMENT
NO ASTERISK, TITLE PAGE/SUMMARY OF CHANGE PAGE ONLY

AT03-76SF76026

FORM 734-C REV. 11-77

DISCLAIMER

TABLE OF CONTENTS

FIGURES

FIGURES - contd.

TABLES

I. BACKGROUND

Tests were concluded in March 1977 on a chain hoist system for the Clinch River Breeder Reactor Ex-vessel Transfer Machine (CRBR-EVTM). These tests subjected the hoist system to 5 years (16,000 cycles) of simulated service in 400°F liquid sodium (Ref. 1). Sodium carryover became evident during the initial phases of the test, that is, sodium was deposited on the chain links and transferred to the drive system components (drive pocket-wheel, idlers, takeup pocket-wheel, and pocket-wheel guide caps) as well as to other chain links. As the test progressed, the chain links became completely coated and the quantity of solid sodium deposits transferred to the drive system components increased the drive load such that overloading and/or jamming of the system occurred in two separate incidents.

Limited carryover was found to be desirable because the solid sodium acts as a quasi lubricant which helps to reduce wear. However, such carryover must be minimized to prevent system overloading and jamming, and also to avoid excessive amounts of radioactive material being carried into the shielded hoist drive system compartment.

In order to get a measure of sodium carryover in a year of simulated operational cycles, the hoist chamber and all hoist components were thoroughly cleaned prior to the fifth year of testing. As application of the refueling cycles progressed, it became evident that coating of the chain and resultant sodium carryover were not occurring as in previous tests. At the end of the 160 refueling cycles, only a very light coating of sodium was evident on the chain and no sodium could be observed on the pocket-wheels or protruding from the guide cap slots.

The absence of sodium on the pocketwheels and caps was confirmed when the hoist was disassembled for post-test inspection. Approximately one ounce of sodium was removed from the chain and less than an ounce was found on the drive system components. This was not consistent with the preceding four years of testing in which substantial amounts of sodium were deposited on the drive components. It was felt that the purity of the sodium and the cover gas had a direct effect on the rate of deposition.

II. OBJECTIVE

The objective of this test was to establish the specific conditions required to prevent or limit the amount of sodium transferred to the hoisting chain and consequently carried over to the drive system components. Specifically, the objective was to 1)identify the factors contributing to sodium carryover and 2) to evaluate their influence on the quantity of carryover.

III. TEST ARTICLE DESCRIPTION

The existing and previously tested EVTM chain hoist system, Figure 1, was used for this test (ref. 1). The hoist system was comprised of a 316 stainless steel pocketwheel (N099002068) and a chain guide cap (N099002465) assembly plus the standard 3/8-inch Columbus McKinnon Corp. "Star 75" chain. An identical pocketwheel guide cap assembly and two idler wheels were used for chain takeup on the unloaded side of the drive wheel.

In addition to the drive system, a series of short pieces of chain and flat test coupons was used to evaluate the sodium pickup and carryover for various metals and surface conditions. Table I shows the coupon configuration and the material/surface preparation combinations used in the test. Figure 2 shows the test article installation configuration.

IV. TEST PROCEDURE

Tests were conducted per AI Test Plan, N707TP830008, (Ref. 2) and Development Test Procedure, N707DTP830012, (Ref. 3) which are summarized below -- with the noted exceptions:

A. Pre-Test System Modifications

The chain hoist mechanism used in the CRBRP EVTM was employed in the test with the following changes. The 1100 lb. chain weight was lowered to the bottom of the sodium tank and a new length of 3/8" "Star 75" steel chain was installed with a 100 lb. ballast attached to the lower end as shown in Figure 2.

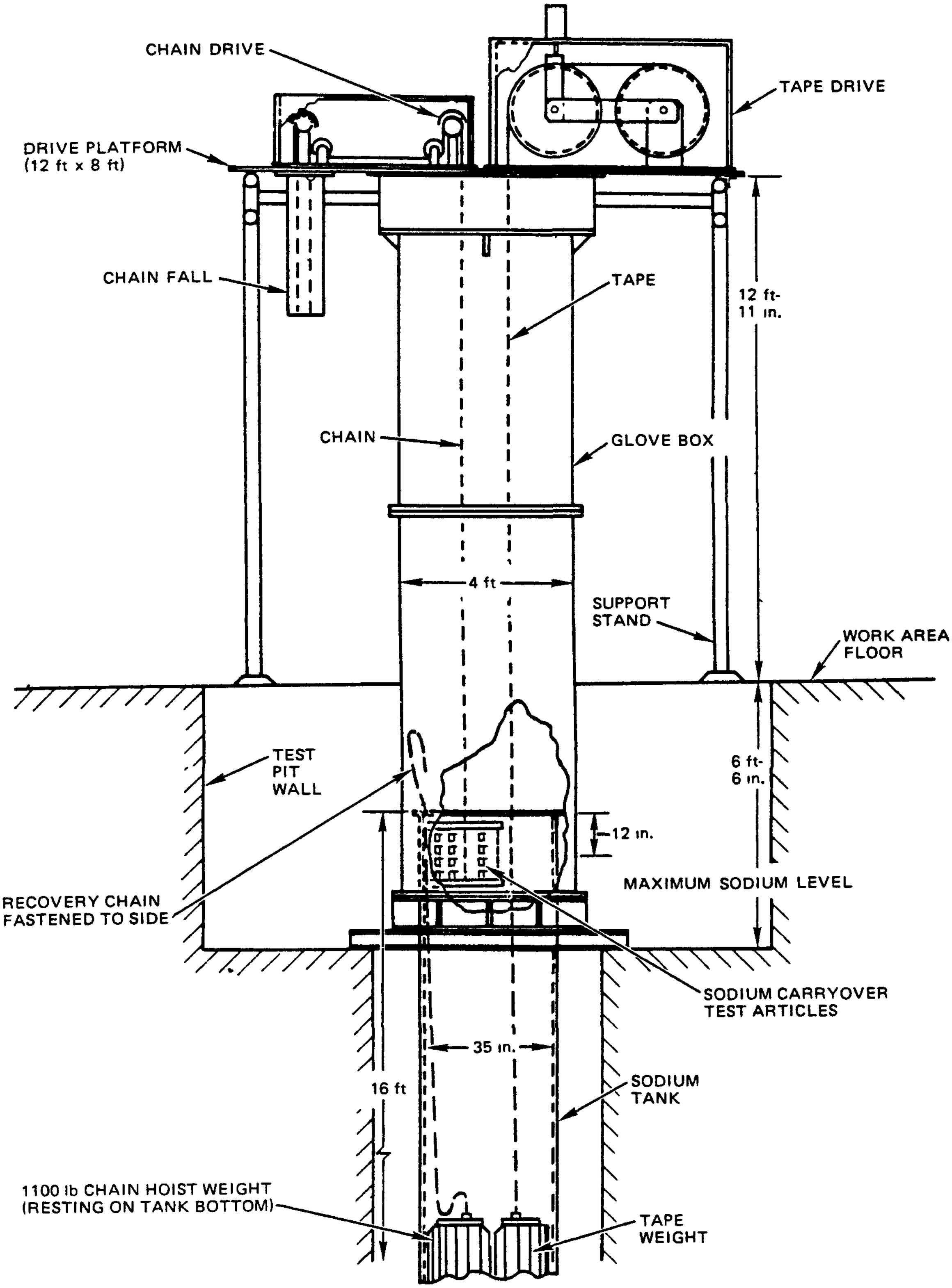
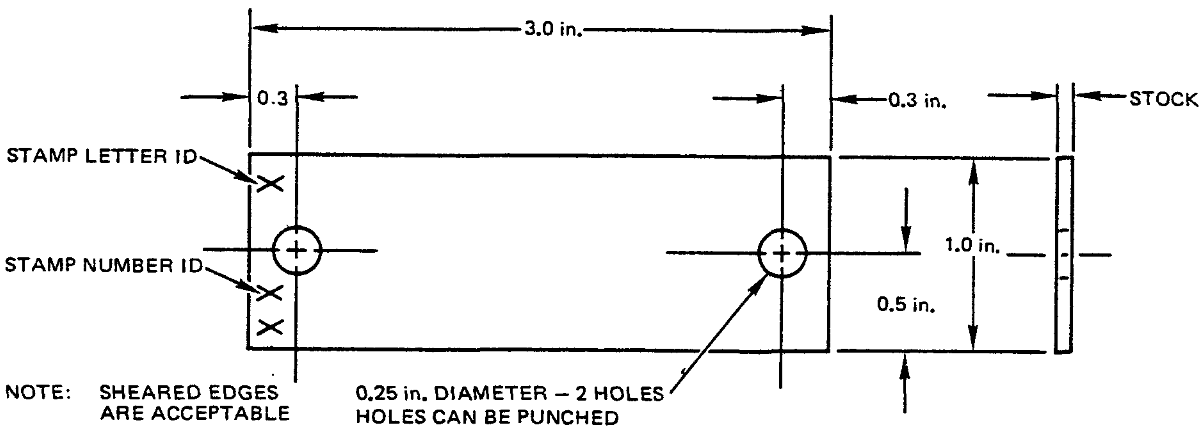


Figure 1 EVTM Grapple Chain Tape Test Fixture Layout

TABLE 1

TEST SPECIMEN MATERIALS



Total No. Required	Material	Thickness	Surface Preparation	Material Specification	Identification	
					Letter	Number
40	1020 Steel	0.050	Cleaned	Ultrasonic Dowclene Bath	A	1 to 40
40	1020 Steel	0.050	Oxide Finish	MIL-C-13924, Class I	B	1 to 40
40	1020 Steel	0.050	Chrome Plated	AI Spec N001A0109001, Type II, Class A	C	1 to 40
40	1020 Steel	0.050	Tin Plated	MIL-T-10727, Type I, 0.2 to 0.4 Mil	D	1 to 40
40	1020 Steel	0.035	Nickel Plated	QQ-N-290, Class 2, 0.2 to 0.4 Mils	E	1 to 40
40	Type 304 Stainless Steel	0.035	Cleaned	Ultrasonic Dowclene Bath	F	1 to 40
40	Type 304 Stainless Steel	0.035	Oxide Finish	MIL-C-13924, Class 2	G	1 to 40
40	Type 304 Stainless Steel	0.035	Cleaned	AMS 5519F	H	1 to 40
40	Inconel	0.035	Cleaned	AMS 5596B	I	1 to 40
40	Steel	3/8 Chain	*	AISI 4615	J	1 to 40
40	Stainless Steel	3/8 Chain	Cleaned		K	1 to 40
40	Steel	3/8 Chain	Chrome Plated	AISI 4615, QQ320, Class 2a	L	1 to 40

*Burnished, tested in 400°F Sodium, alcohol cleaned, ultrasonic Dowclene bath.

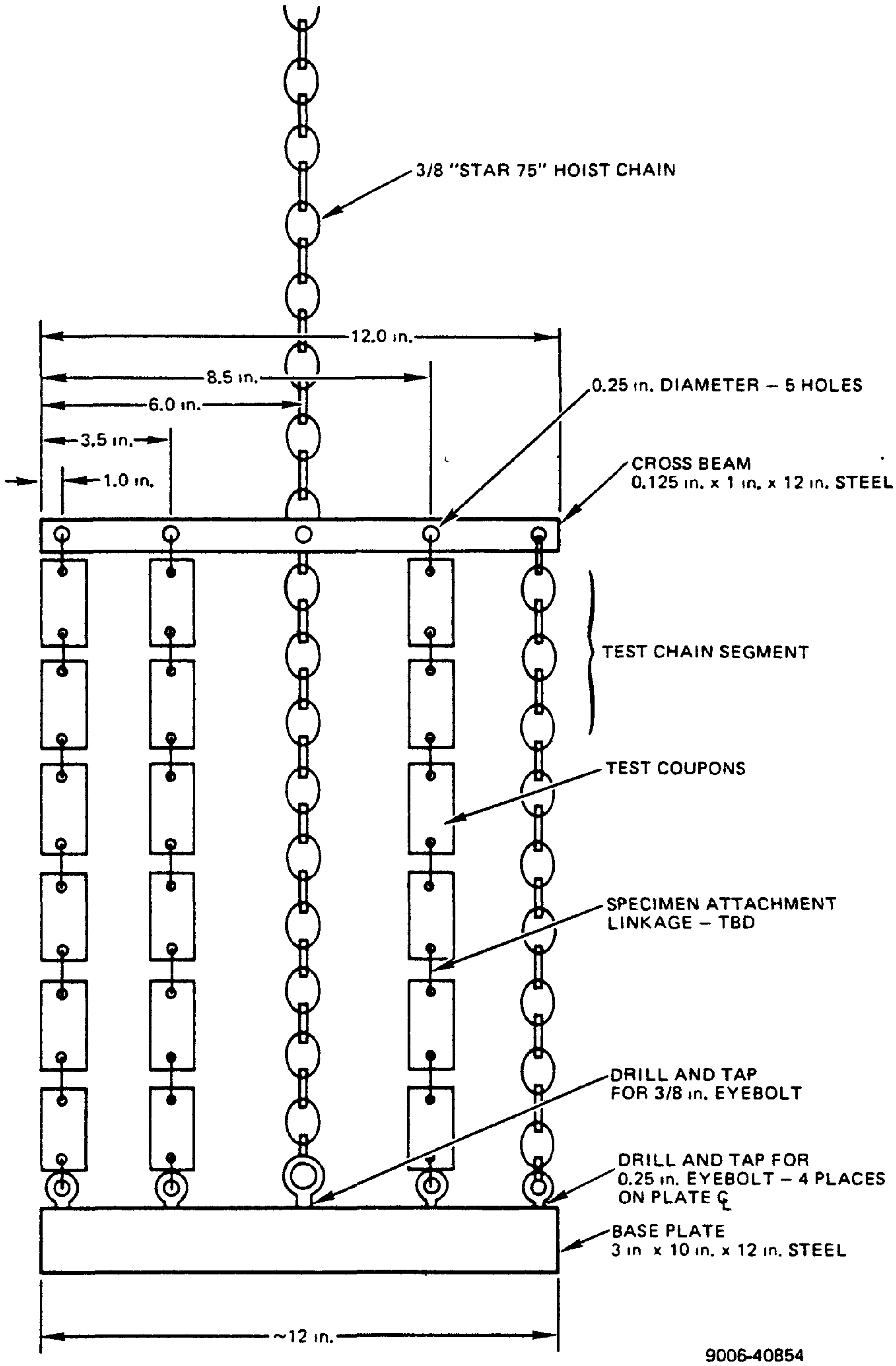


Figure 2. Test Article Installation

The control console and circuitry were modified to eliminate tape operation and to incorporate the test sequence illustrated in Figure 3.

B. Test Sequence

A test matrix, Table II, was formulated and modified as required during testing to maximize the information gained and minimize the number of tests. Each test was conducted by randomly selecting a set of test coupons to complete the matrix of Table I and subjecting them to a minimum of one year (160 cycles) of simulated operation. Sodium coating of the chain and metal test coupons was then analyzed as a function of test variables.

Midway through the test matrix, tests were transferred to small argon atmosphere glove boxes in which the oxygen and moisture content in the atmosphere could be more closely regulated. The sodium immersion sequence was simplified to an in and out cycle with 2 minutes sodium immersion and 5 minutes dwell in the gas atmosphere per cycle.

V. TEST RESULTS

Results of the carryover tests are presented below. Tests were conducted per N707DTP830012, as summarized above with the noted exceptions. Details of testing are recorded in AI Laboratory Notebook N17010. Test coupons and other associated charts will be stored for a minimum of one year. Descriptions of post-test coupons were recorded photographically and summarized in the laboratory notebook.

A total of 18 tests were conducted. Table III summarizes the various test conditions and Table IV summarizes the degree of test specimen sodium coating based on visual observation of the post-test conditions.

A. Chain/Tape Vessel Tests (Test 1-9A)

The first nine tests were conducted in the existing chain and tape vessel illustrated in Figure 1.

1. Test 1

The initial test was run through 2 life times (320 immersion cycles) of simulated operation with 400°F sodium having an oxygen content of 7.9 to 9.8 ppm. The argon cover gas purity was ~ 6 ppm

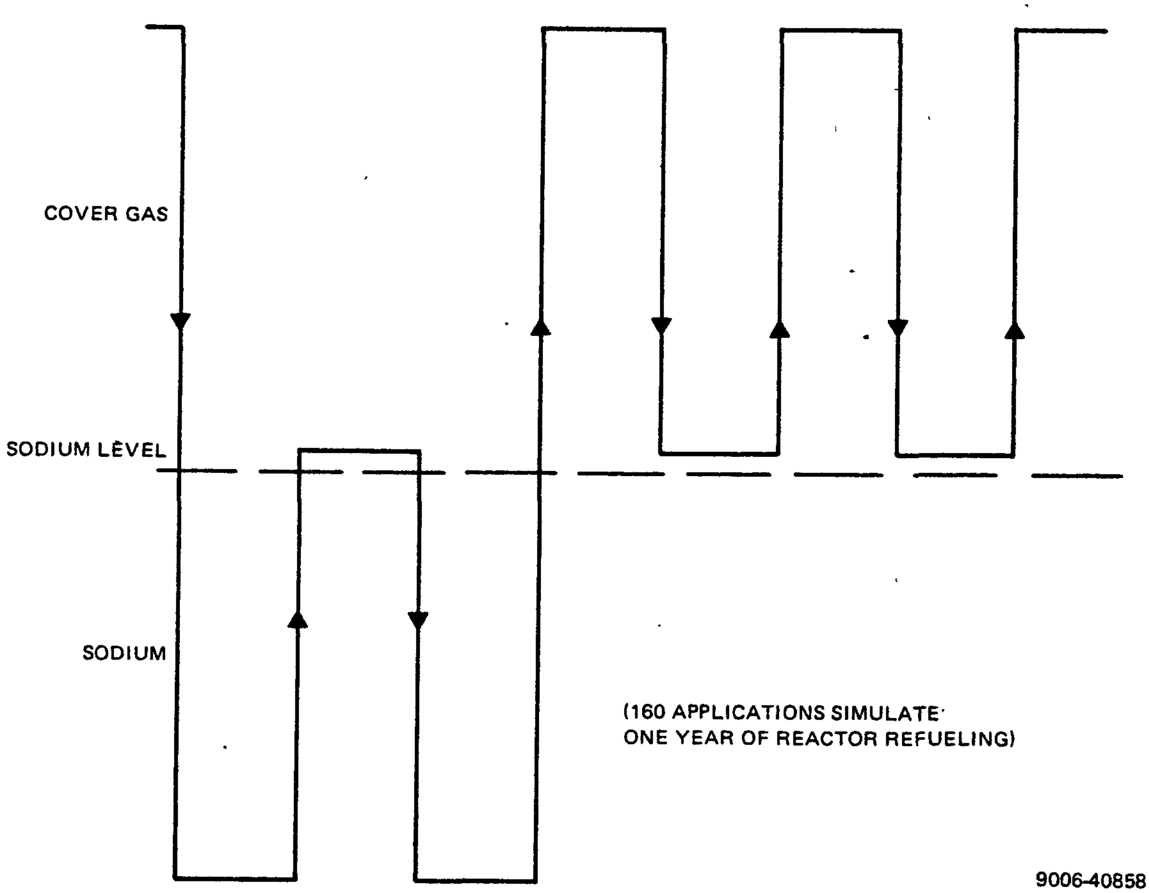


Figure 3. Test Spectrum

TABLE II

Na CARRYOVER TEST-MATRIX

Test #	Gas	Sodium Temperature °F	Sodium O_2 Content ± 5 ppm	Cover Gas Contaminant		Chain Speed
				O_2 ± 5 ppm	H_2O Vapor ± 5 ppm	
1	Argon	400	25	10	10	12
2			>10	10	10	
3			TBD	50	10	
4				75	10	
5				10	50	
6				10	75	
7		↓	↓	50	50	
8		600	25	10	10	
9			>10	10	10	
10			TBD	50	10	
11				75	10	
12				10	50	
13				10	75	
14	↓	↓		50	50	
15	Helium	400		50	50	
16		400		10	10	
17		600		50	50	
18	↓	↓		10	10	↓
19	TBD	TBD	↓	TBD	TBD	30

TABLE III

TEST CONDITIONS

Test Group	Sodium Temperature (°F)	Nominal Average Cover Gas Temperature (°F)	Nominal Cover Gas Pressure (in. H O)	Immersion/ Withdrawal Speed (ft/min)	Cover Gas Moisture Content (ppm)	Coven Gas O_2 Content (ppm)	Sodium O_2 Content (ppm)	Test (1) Duration (years)	Degree of Wetting (Estimated) (%)	Comments
1	400	120	1-3	10.3	~1	~6	7.9, 9.8	2	See Table 4	
2	400	120		10.3		<46 (2)	8.7, 8.7	1		
3	400	120		-		~6	8.7, 12.0	>72 h		Sodium soak test only; no cycling.
4	400	120		10.3		<46	12.0, 13.3	1		Chain removed for cleaning; 6 oz. sodium on chain, 4 oz. on hoist components.
5	400	120				<25 <47 (3)	8.6 8.7	1 1		
6	400	120				<25	8.7, 9.1	1		
7	400	120				~10	8.7, 9.1	0.6		
8	400	120		10.3		~6	9.1, 11.9	1.4		Chain jammed, removed for cleaning; 6 oz. sodium on chain; 4 oz. on other hoist components.
8A	400	120		-		~6	9.1, 11.9	306 h		Sodium soak test only; no cycling.
9	400	120		10.3		4 to 13	9.0, 13.0	5.8		Chain jammed.
9A	400	120		-		4 to 13	9.0, 13.0	2000 h		Sodium soak only.
10	~400	120		1 to 2		~1	4.3, 4.7	5		First glove box test. (4)
11	~400	120				~10	~9	1		
12	~400	120				~5	~13	1		Oxygen spray. (5)
13	400	100				~1	4.3	2		
14	400					~10	~5	2		
15	400					~20	~7	2		
16	400				~1	~50	8.9	6 + 200 h		
17	400				~50	<1	~4	2		
18	400	100	1-3	1 to 2	~25	<1	~4	2		

(1) Years of simulated refueling cycles.

(2) Spiked argon with 46 ppm was quickly gettered; consequently, the 46 ppm O_2 gas was applied only at the upper region of the chamber where the specimens rested during the 5 minutes dwell.

(3) During the 2nd year of test, one-fourth of test was run with 100 ppm O_2 purge gas applied to chamber.

(4) Tests switched from chain-tape test vessel to small argon glove box — O_2 injected, purification system off.

(5) Oxygen injected by directed spray, glove box purification system on.

TABLE IV
SUMMARY OF ESTIMATED SODIUM COATING

Material	Condition	Degree of Sodium Coating (Estimated %)																			
		Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 8A	Test 9	Test 9A	Test 10	Test 11	(4) Test 12	Test 13	Test 14	Test 15	Test 16	Test 17	(6) Test 18
1020, Bare	"New" Specimens with no previous sodium carryover test exposure	50	95	(1)	98	100	92	100	98	(1)	100	(1)	70	70	~50	<10	<20	<20	<20	80	15
1020, Oxide Coat		50	90		98	98	100	95	90		100		90	90	~50	<10	<20	<20	<20	95	25
1020, Chrome Plated		60	95		100	98	100	95	98		100		90	85	~60	<10	<20	<20	<20	95	25
1020, Tin Plated		100	100	75 (2)	100	100	50	80	98	25 (2)	100		40	100	100	100	100	(5)	(5)	100	40
1020, Nickel Plated		60	90	(1)	100	100	90	95	90	(1)	100		25	60	~60	<10	<20	<20	<20	85	25
304, Bare		60	90		100	99	25	60	70		100		5	40	~50	<10	<20	<20	<20	85	20
304, Oxide Coat		30	70		98	98	97	85	98		100		10	40	~50	<10	<20	<20	<20	90	30
301, Bare		60	95		100	100	95	70	95		100		10	30	~40	<10	<20	<20	<20	90	30
Inconel		50	80		95	100	40	40	95		100		15	15	~20	<10	<20	<20	<20	90	50
Stainless Steel Chain		60	80		90	99	40	25	80		100 (3)		-	-	-	-	-	-	-	-	-
Chrome Plated 4615 Chain		70	85		90	99	30	30	80		100 (3)		-	-	-	-	-	-	-	-	-
4615 Chain (Previously tested and cleaned)		50	75		90	99	60	30	80		100 (3)		-	-	-	-	-	-	-	-	-
1020, Bare	Specimens previously subjected to sodium carryover tests, cleaned in alcohol followed by ultrasonic Dowclene bath	-	95	(1)	95	90	98	85	100	(1)	100	← No additional tests →									
1020, Oxide Coat		-	90		95	98	95	95	98		100										
1020, Chrome Plated		-	95		100	100	100	90	95		100										
1020, Tin Plated		-	70		70	85	95	98	98		100										
1020, Nickel Plated		-	90		95	98	95	95	98		100										
304, Bare		-	50		90	100	100	50	98		100										
304, Oxide Coat		-	90		95	90	95	60	95		100										
301, Bare		-	65		95	99	98	90	90		100										
Inconel		-	80		90	85	98	30	90		100										
Stainless Steel Chain		-	-	-	-	-	40	-	85		-										
Chrome Plated 4615 Chain		-	-	-	-	-	40	-	85		-										
4615 Chain (Previously tested and cleaned)		-	-	-	-	-	20	-	85		-										

(1) Test was a sodium soak; no cycling into the cover gas was conducted. Zero wetting; sodium droplets clinging to surface of some specimens (up to ~10% surface coverage).
(2) 100% wetting occurred on immersion; but under prolonged sodium exposure, surface turns "gold" (probably tin oxide) and wetting on this surface diminishes with time.
(3) Except in region of link contact.
(4) Degree of coating obscured by heavy oxide layer on sodium and coupons.
(5) Tin coupon omitted from matrix.
(6) Degree of wetting same as Test 17, 20 h.

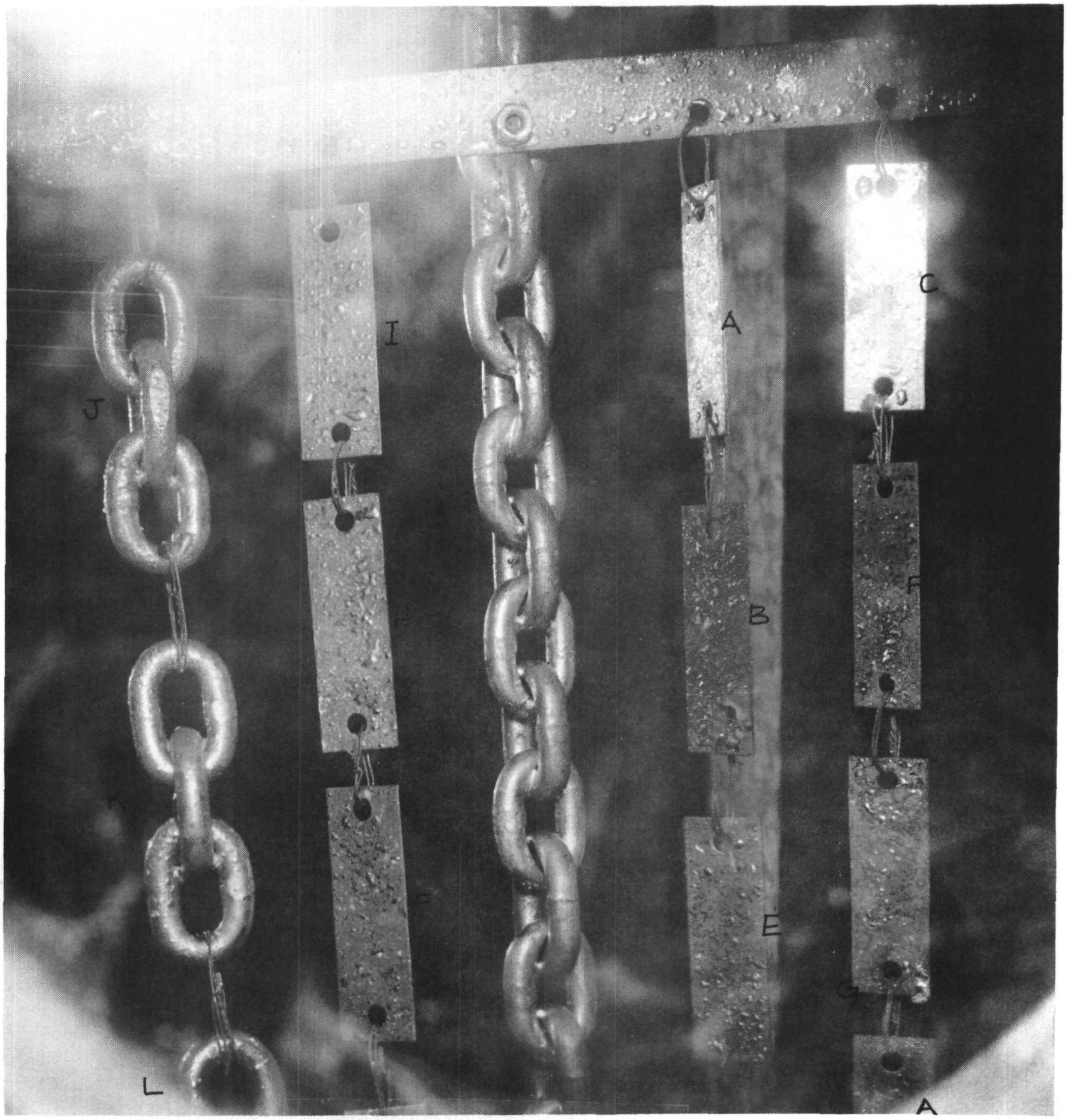
and 0.25 ppm moisture. The tin plated specimen wet during the first immersion cycle and after one year of simulated reactor refueling cycles, all other coupons were partially coated with small droplets covering 30-40% of the surface. All of the chain segments appeared to be well coated, but it was visually evident that complete wetting had not occurred. Approximately one foot above the cross-bar supporting the test articles, the load chain was considerably less coated -- with tiny droplets of sodium on ~25% of the surface.

In spite of the minimal amount of sodium transferred to the load chain, significant carryover of sodium occurred to the upper section of chain which was never submerged in the sodium pool. This transfer occurred when the molten sodium was stripped from the partially coated lower chain section by the pocketwheel guide-cap assemblies and redeposited as it froze on the cold upper chain section. Sufficient sodium was accumulated on some links to form small "wings" as they passed horizonatally through the pocketwheel. A second year of simulated cycles was accumulated with a small increase in sodium adhering to the test specimens. The tin plated coupon was the only specimen to completely wet.

Figures 4 and 5 show both sides of the test coupons at the end of 2 years simulated operation. The smooth appearance of the wetted tin plated coupon (D-S/N 22) contrasts sharply with the spotty sodium coatings on the other specimens. Table I correlates coupon material identifications with the figures and Table IV indicates the visually observed degree of sodium coating.

2. Test 2

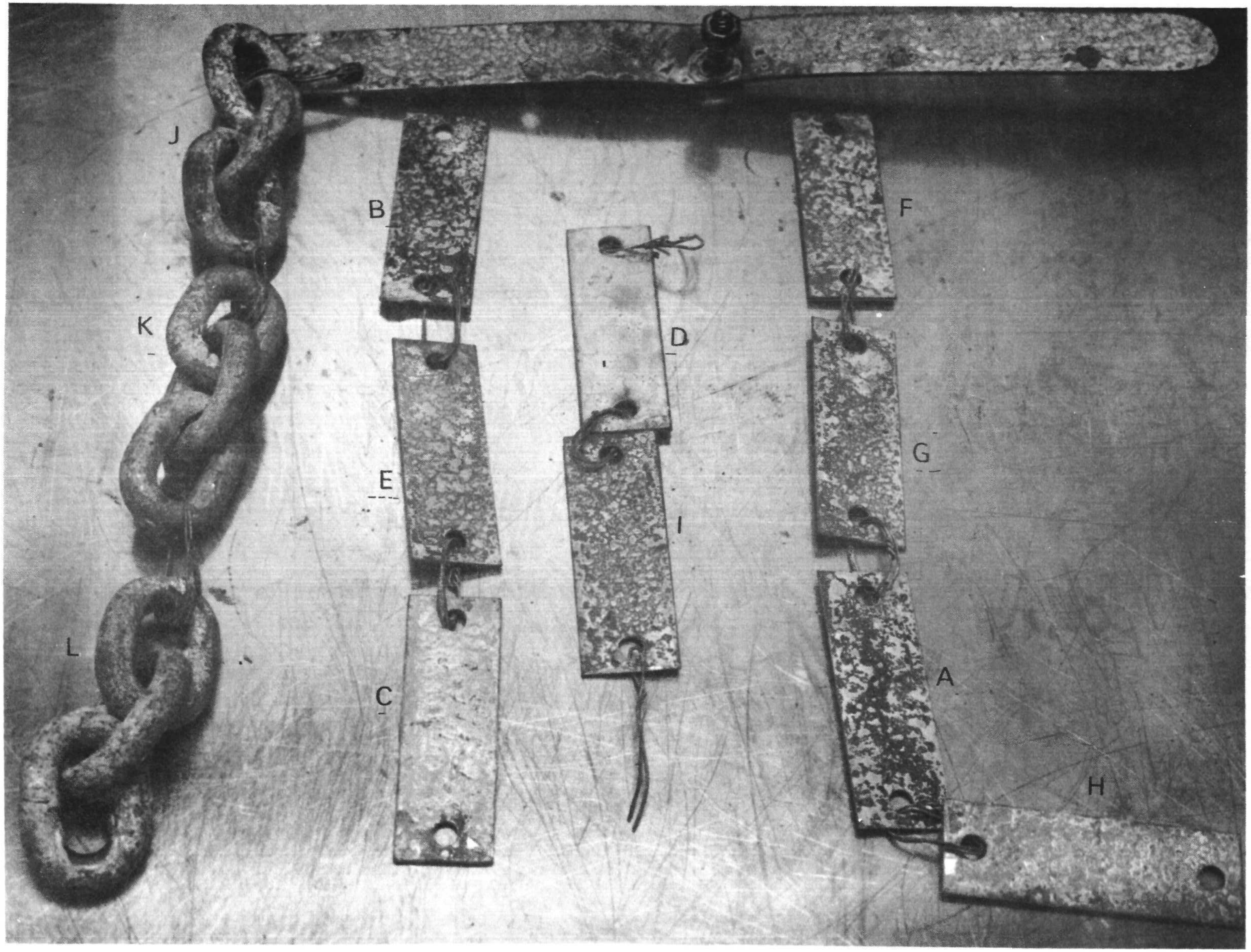
Specimens for Test 2 were selected to duplicate Test 1 materials. The specimens from Test 1 were cleaned with alcohol, ultrasonically cleaned with Dowclene, and included in the test matrix to study the effect of specimen cleaning on wetting.



Test No. 1
Sodium Adherence on Test Coupons

Figure 4

9006-40823



Test No. 1 Opposite Side of Test Coupons

Figure 5.

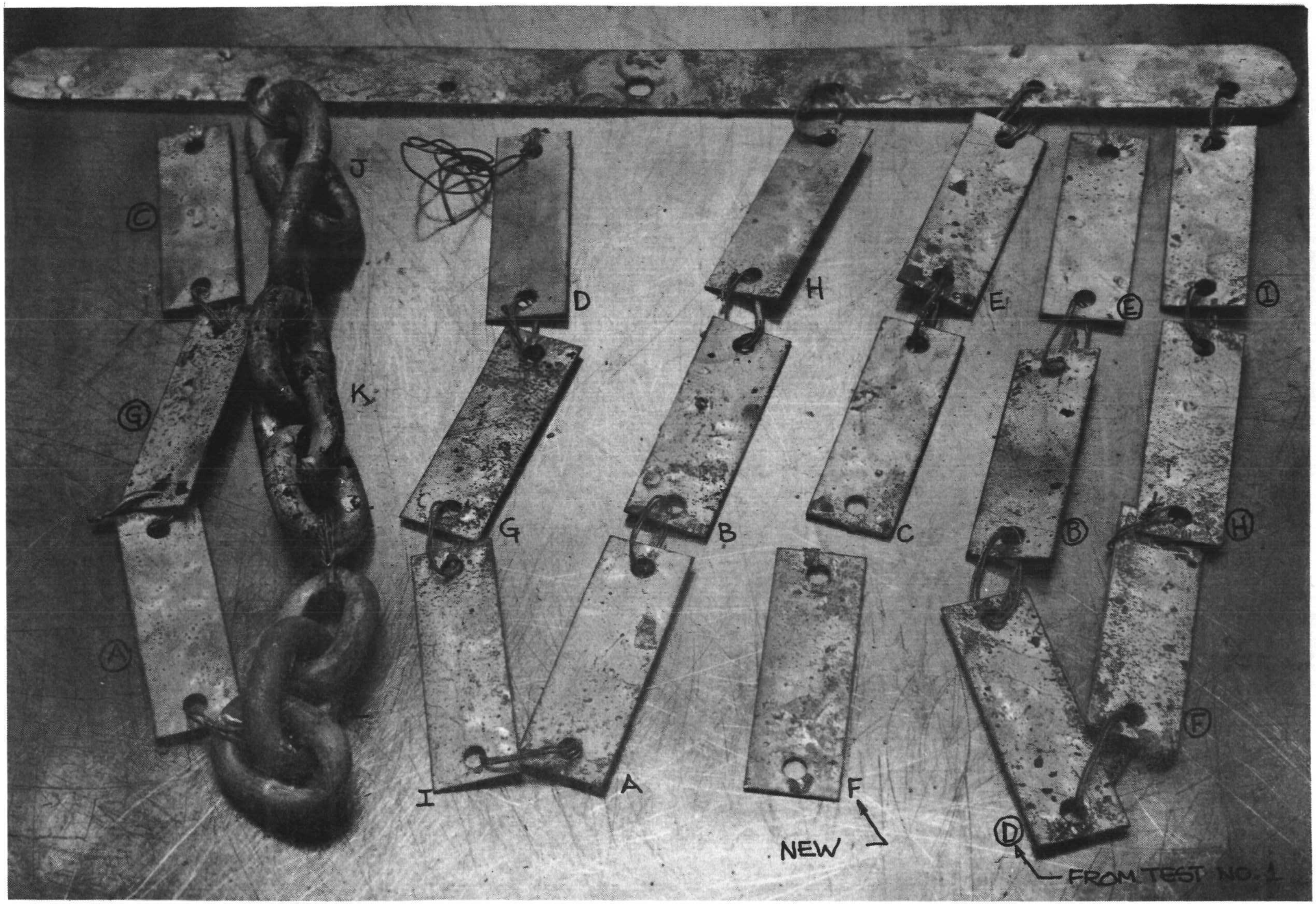
9006-40829

One year of simulated testing was completed in 400°F sodium with an oxygen content of 8.7 ppm and an argon cover gas with a nominal 46 ppm oxygen and 0.25 ppm moisture. The 46 ppm O_2 could not be maintained constant throughout the entire test chamber due to the rapid gettering by the sodium. Consequently, pure O_2 was introduced into the chamber at ~0.1 CFH to achieve the desired concentration. If the inflow was decreased, the O_2 concentration quickly dropped due to the sodium gettering; and if a constant inflow was maintained, a heavy oxide film was built up on the sodium surface. The oxygen inlet port was moved to the upper end of the environmental chamber adjacent to the rest position of the coupons during their 5 minute dwell. Argon with 46 ppm O_2 was subsequently introduced into the test chamber at this position while the coupons were in the dwell. This achieved the desired O_2 level and precluded excessive oxide build-up on the sodium surface.

As noted in Table IV, the degree of apparent wetting was substantially greater for both the new and the previously tested specimens. The major difference in the test was the increased O_2 content in the gas environment. Figures 6 and 7 illustrate the post-test condition of the specimens.

3. Test No. 3

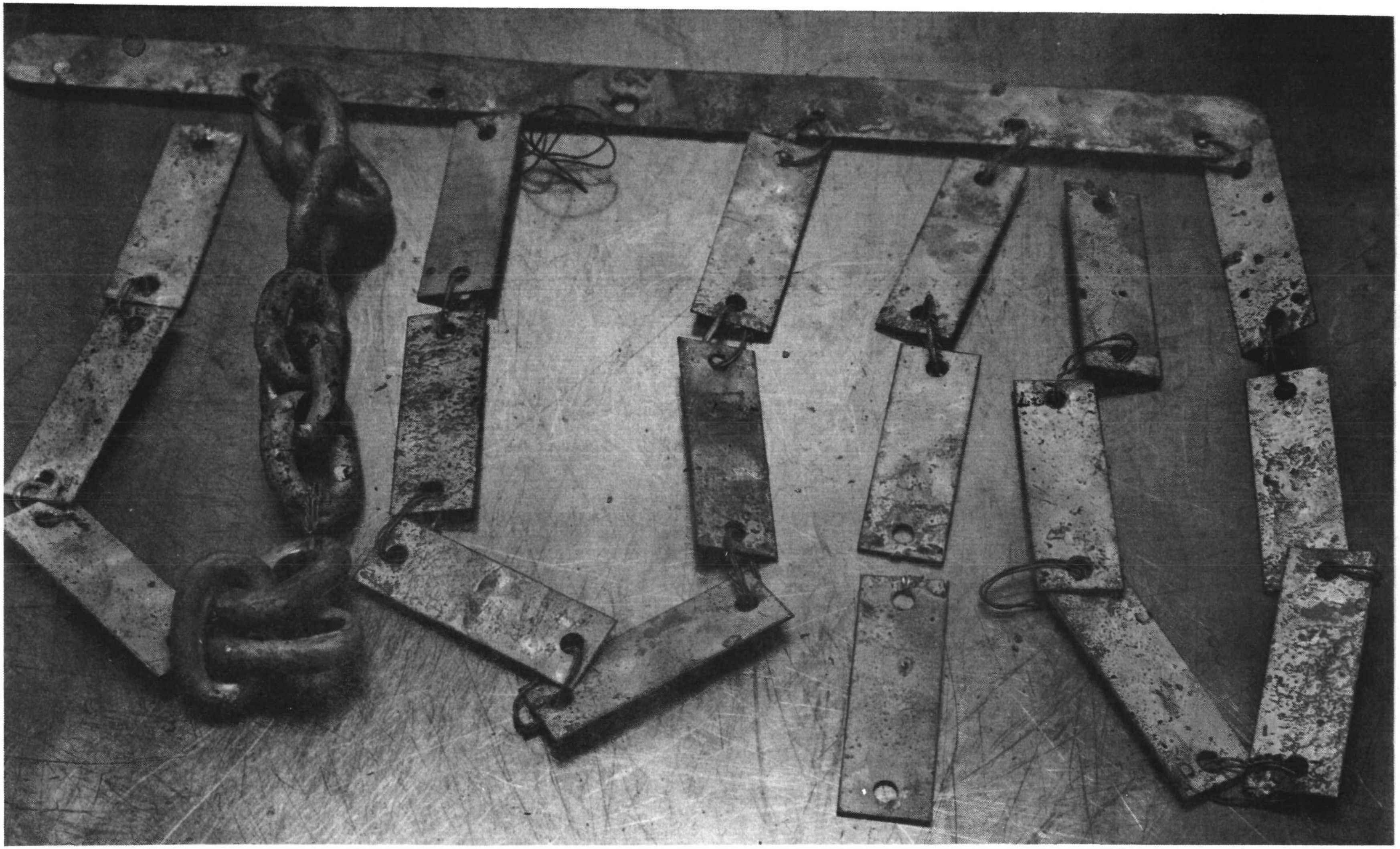
A third group of test articles; two each of the nine "new" specimens, three new chain specimens, and one each cleaned coupon from Test No. 2, was subjected to over 72 hours of soak in 400°F sodium with no cycling into the argon atmosphere. The two new tin-plated coupons were completely wetted and no other coupons, including the cleaned and reused tin plated coupon, had more than 10% of their surfaces covered by droplets of sodium. This was consistent with previous experience where prolonged immersion in 400°F sodium produced no wetting except to tin-plated surfaces. Figures 8 and 9 show the post-test coupons.



Test No. 2 - Post-Test Coupon Condition, Side 1

Figure 6.

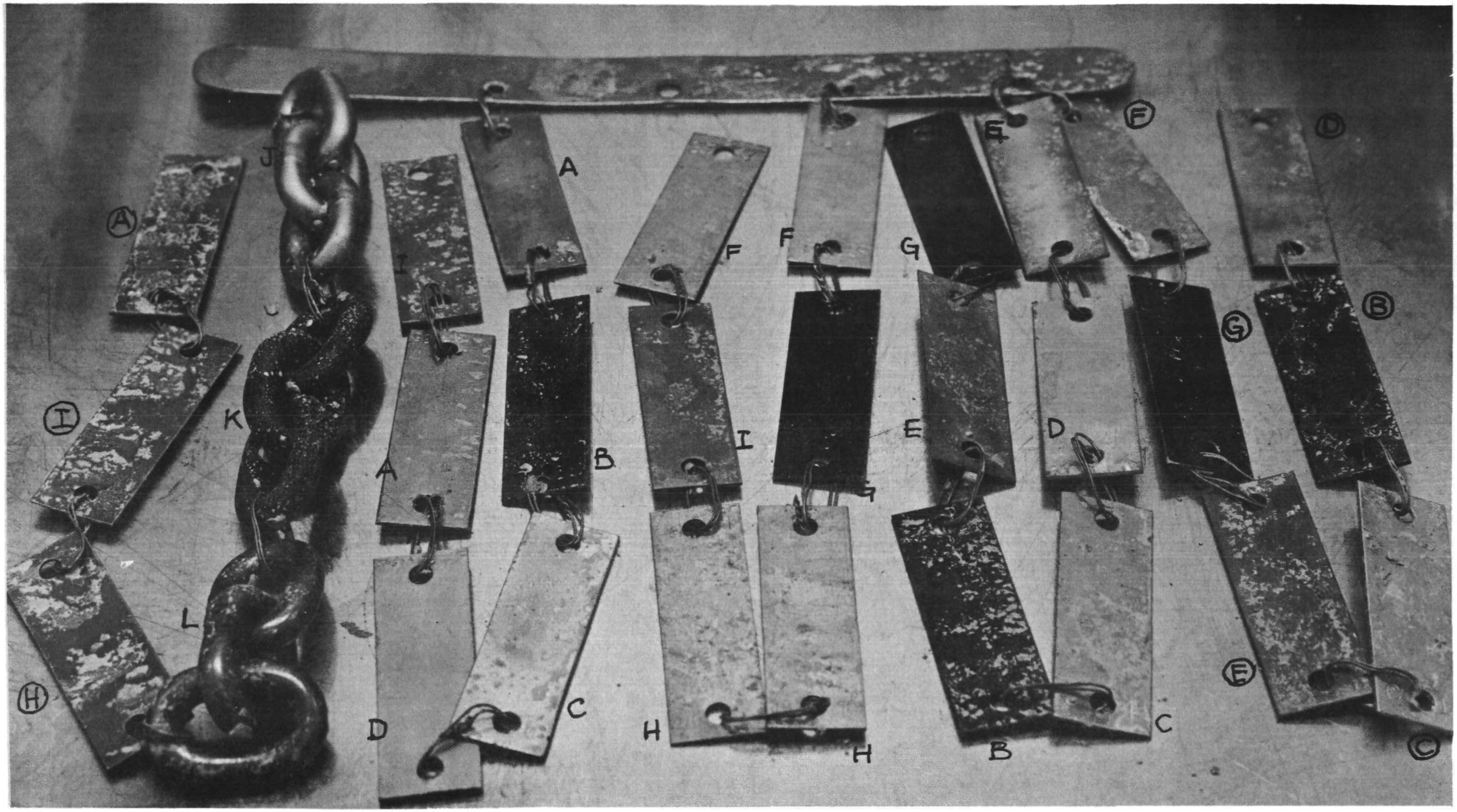
9006-40841



Test No. 2 - Post-Test Coupon Conditions - Side 2

Figure 7.

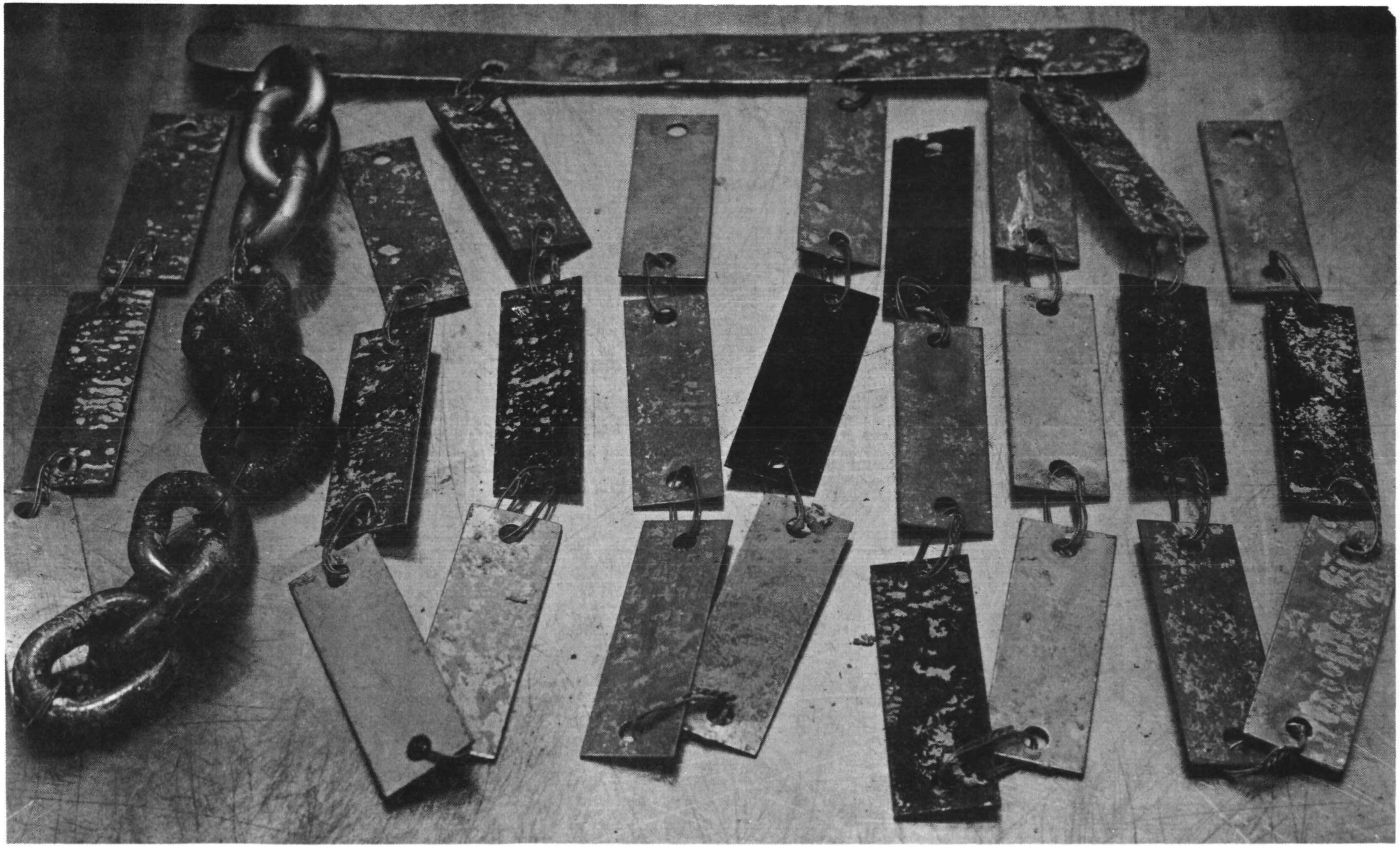
9006- 40840



Test No. 3 - Post-Test Coupon Conditions, Side 1

Figure 8.

9006-40839



Test No. 3 - Post-Test Coupon Conditions, Side 2

Figure 9.

9006-40838

4. Test No. 4

Test No. 4 was a duplicate of Test No. 2, but with the 46 ppm O_2 introduced at the top of the chamber during the 5-minute dwell throughout the entire test. As noted in Table IV, the degree of coating was considerably greater in Test No. 4. The post-test coupons are shown in Figure 10.

5. Test No. 5

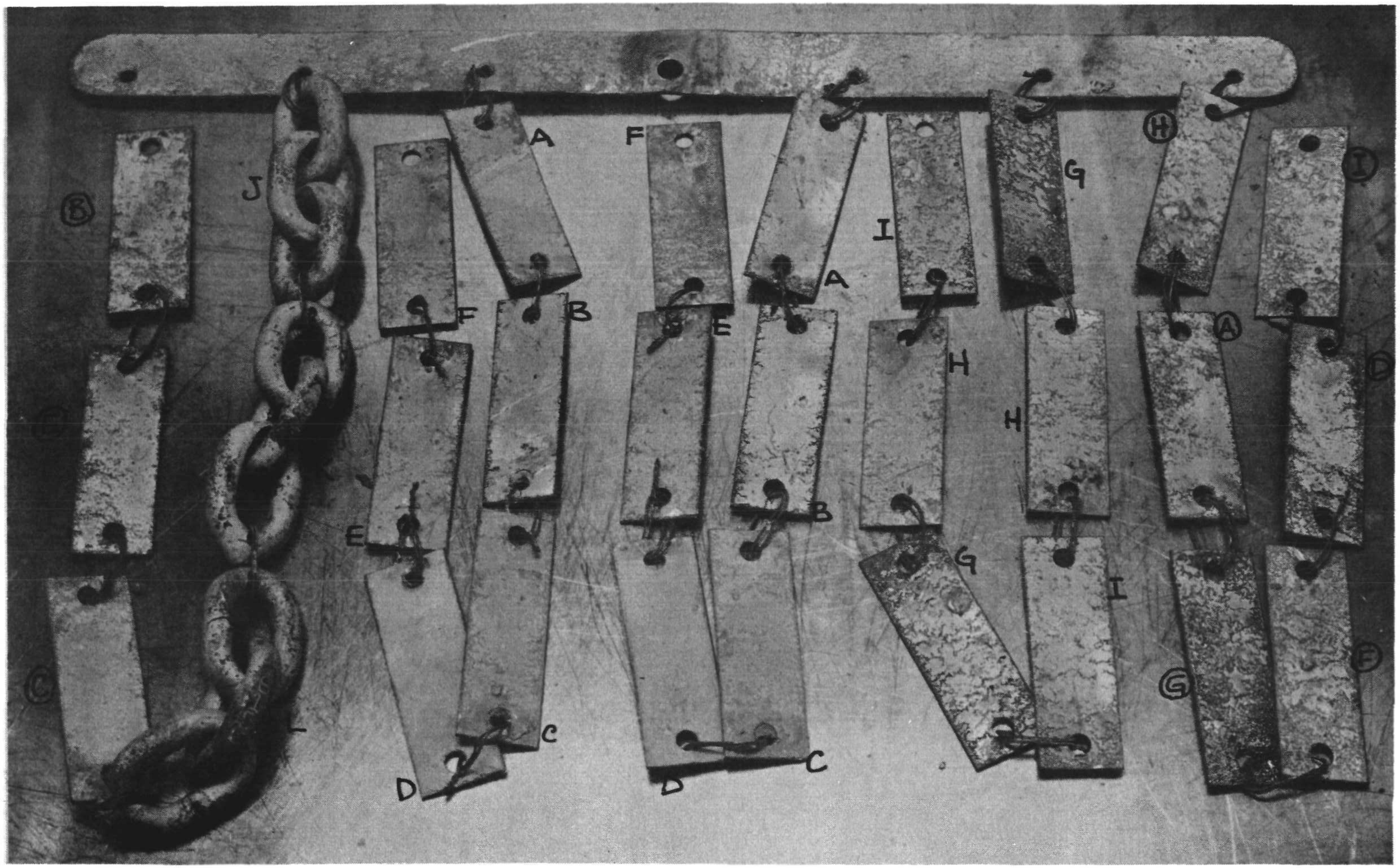
Test No. 5 was conducted at a nominal 25 ppm O_2 level through 2 years of simulated operation. Figure 11 illustrates the general condition of the specimens at that time. All coupons were uniformly coated, on about 50-70% of their surfaces with small droplets of sodium. A truly wetted surface would have a smooth, completely covered, shiny film of sodium. An additional year of operation was run at ~47 ppm O_2 which appeared to increase the amount of sodium coating the coupons. A final year of operation was run at 100 ppm O_2. Visual observation of the coupons at the end of testing showed almost complete sodium coating of all coupons (Table IV). Figure 12 shows the post-test coupons.

6. Test No. 6

Test No. 6 was conducted through 1 year of simulated operation at an argon O_2 level of <25 ppm. As noted in Table IV, the degree of surface coating was approximately equal or slightly less than that observed on Test No. 1, conducted at 6 ppm. Figure 13 shows the post-test coupons after removal from the test vessel. Observation of the coupons prior to removal from the vessel indicated a greater degree of sodium coating than shown in the figure which indicates incomplete wetting or adherence.

7. Test No. 7

Test No. 7 was conducted through an equivalent of 0.6 years of operation (~ 200 cycles) at an oxygen level of ~10 ppm. Coupons appeared to be completely coated when viewed in the test vessel. Typically, when removed from the environmental-chamber and transferred to the glove box for photographing, the sodium droplets



Test No. 4 - Post-test Coupons

Figure 10.

9006-40850

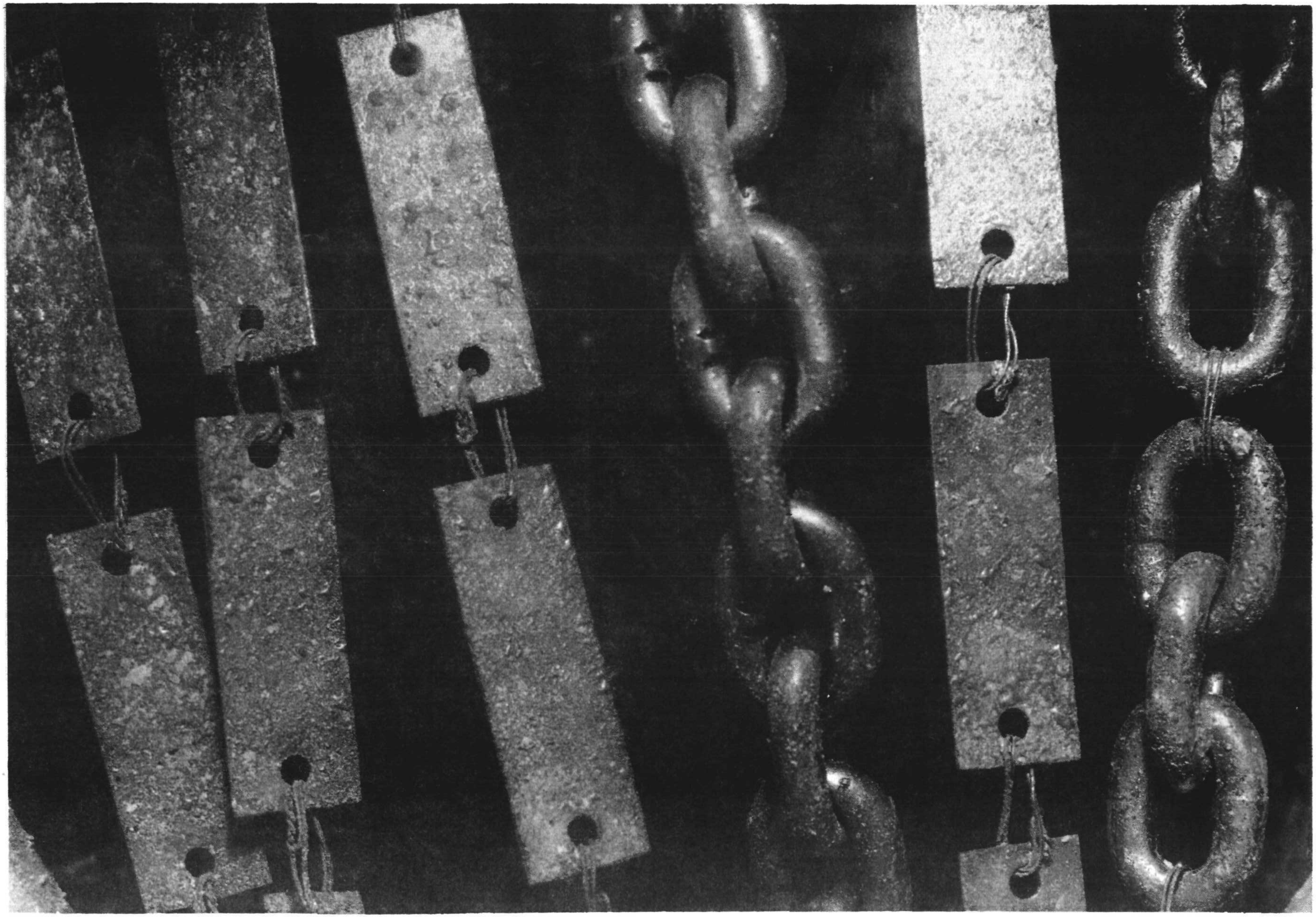
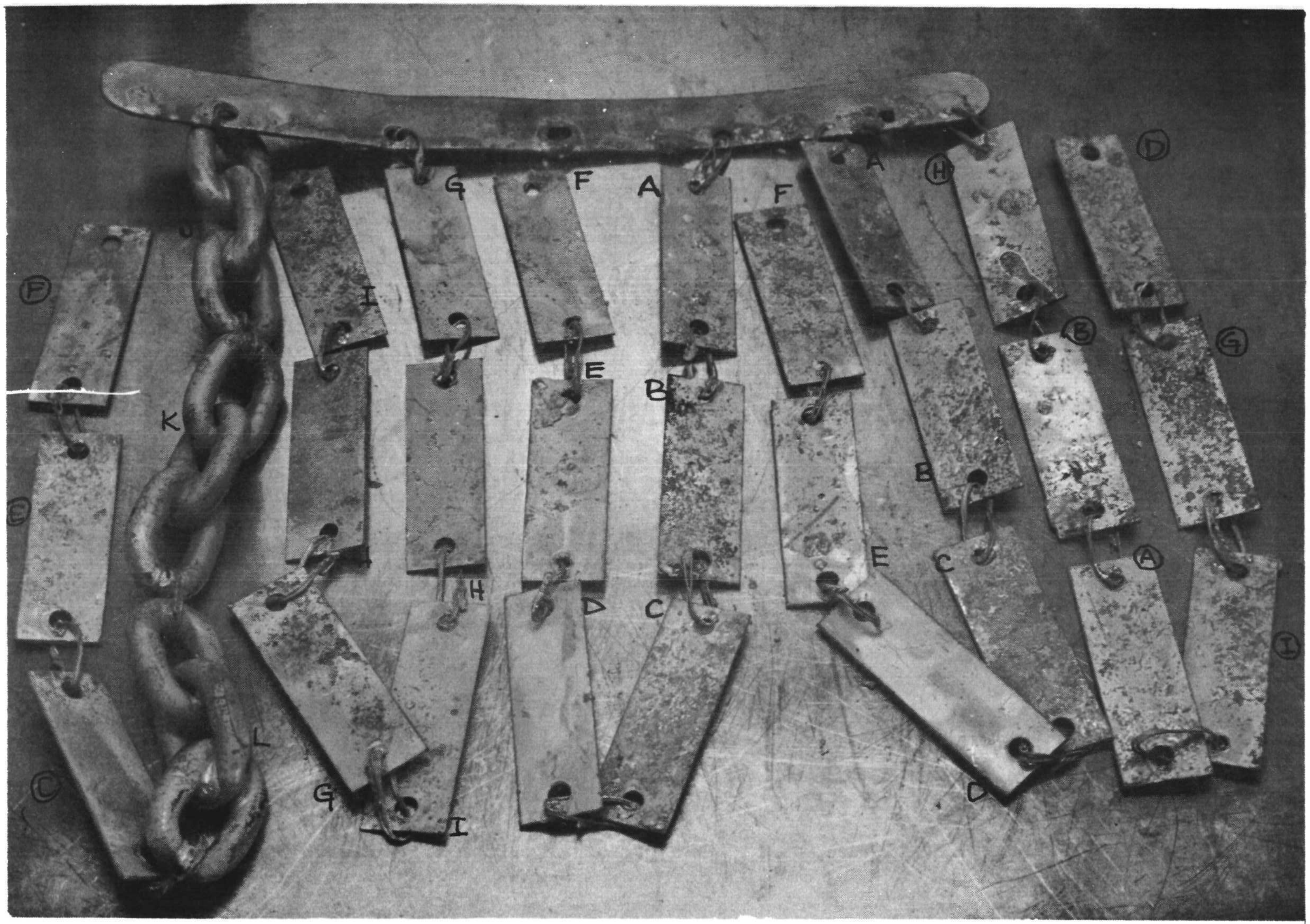
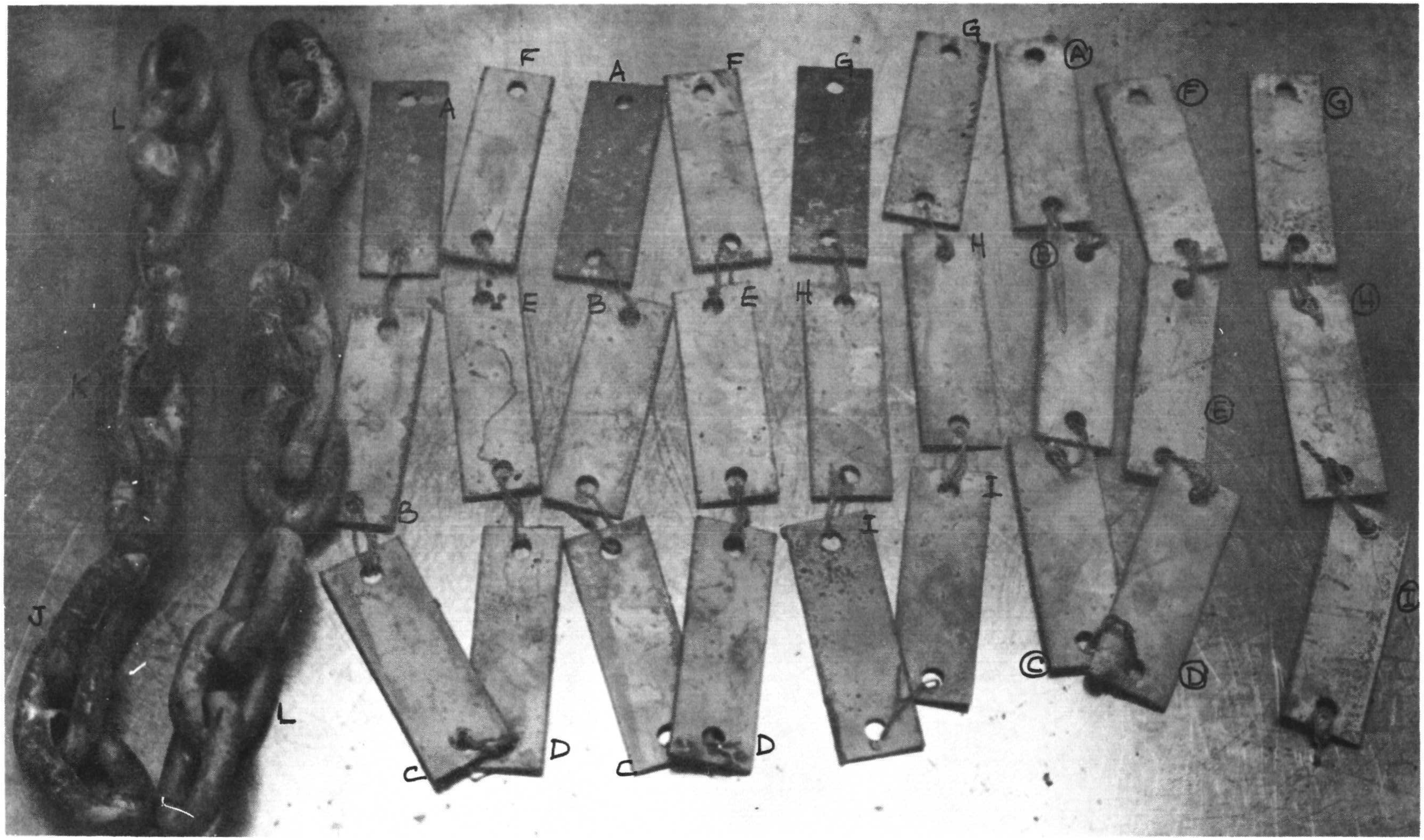


Figure 11. Test No. 5 - General Coupon Appearance

9006-40852



Test No. 5 - Post-test Coupons
Figure 12



Test No. 6 - Post Test Coupons

Figure 13

tended to bead up, which should not occur on a fully wetted surface. The post-test coupons are shown in Figure 14 and Figure 15 shows the apparent wetting between immersed chain links. Table IV shows the estimated percent of sodium coating and as with previous tests, indicated little difference in the percent coating of new or used test specimens.

8. Test No. 8

Test No. 8 was a duplication of tests 1 and 3 and was operated through the equivalent of 1.4 years operation. Near the end of the test, the rear pocketwheel jammed due to excessive sodium carryover and resulted in the specimens being immersed in sodium for ~16 hours. All coupons appeared to be 100% coated, including those previously tested. Table IV coating values were measured after the coupons were transferred from the chamber to the glove box. Their post-test condition is illustrated in Figure 16.

9. Test No. 9

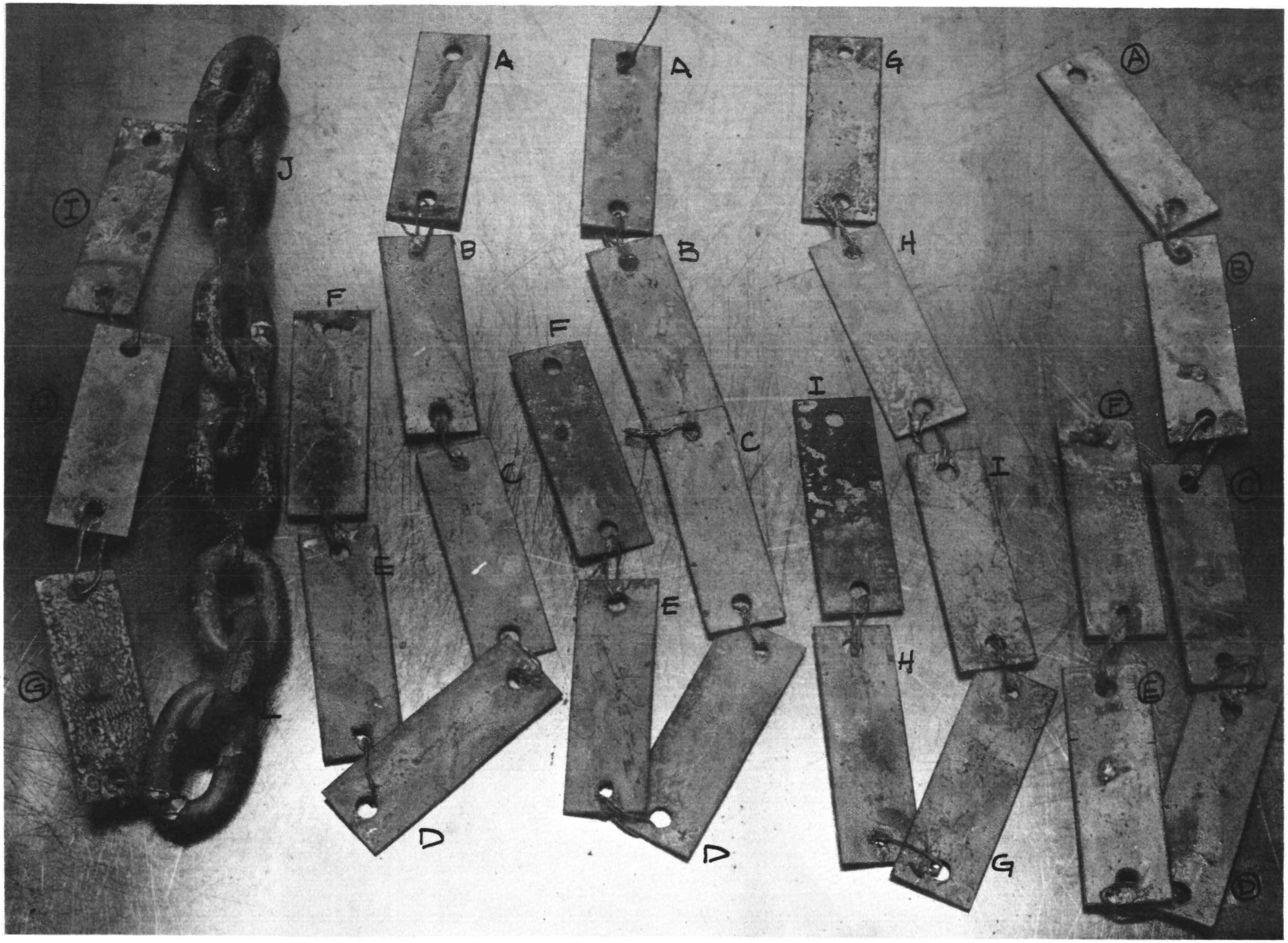
Test No. 9 was operated at an argon gas O_2 level of 4-13 ppm and accumulated an equivalent of ~5.8 years of simulated operation. Testing was terminated after the chain jammed due to sodium carryover and all coupons were observed to be 100% coated with sodium. It was observed that initially coupons had a shiny-sodium coated appearance but with a rough texture. As testing progressed, the surface became smoother -- approaching a true wetted appearance.

10. Tests 8A and 9A

These tests duplicated the full material selection of the above cycling tests, but the coupons were immersed in sodium, without cycling into the argon atmosphere, throughout the test. Test 8A coupons were soaked for 306 hours and Test 9A coupons for > 2000 hours. In both cases the tinned coupons wet almost immediately (coupons were periodically raised out of the sodium for observation of wetting) and sodium coverage of all other coupons was less than 10%.

C. Glove Box Tests (10-18)

Tests were transferred from the EVTM environmental test chamber to a small argon atmosphere glove box where oxygen and moisture partial



Test No. 4 - Post-test Coupons

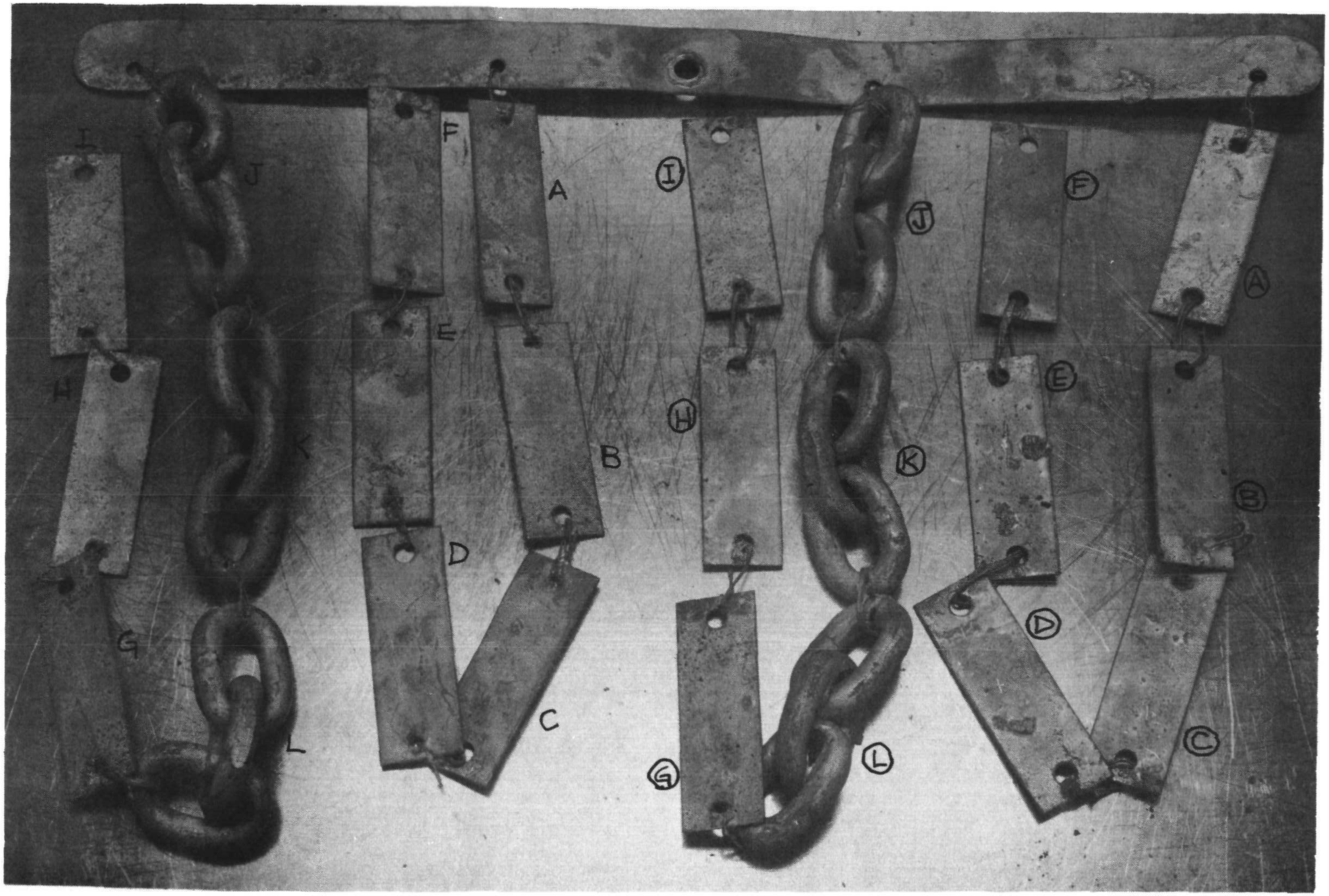
Figure 14

9006-40895

Sodium Bridge Between Chain Links

Test No. 7

Figure 15



Test No. 8 - Post-Test Coupons

Figure 16.

pressures in the atmosphere could be precisely controlled and measured. The glove box, shown in Figure 17, was fitted with a static sodium pot and a mechanism for cycling specimens in and out of sodium. The cycle was set up to provide a 2 minute sodium immersion and a 5 minute dwell in the gas environment.

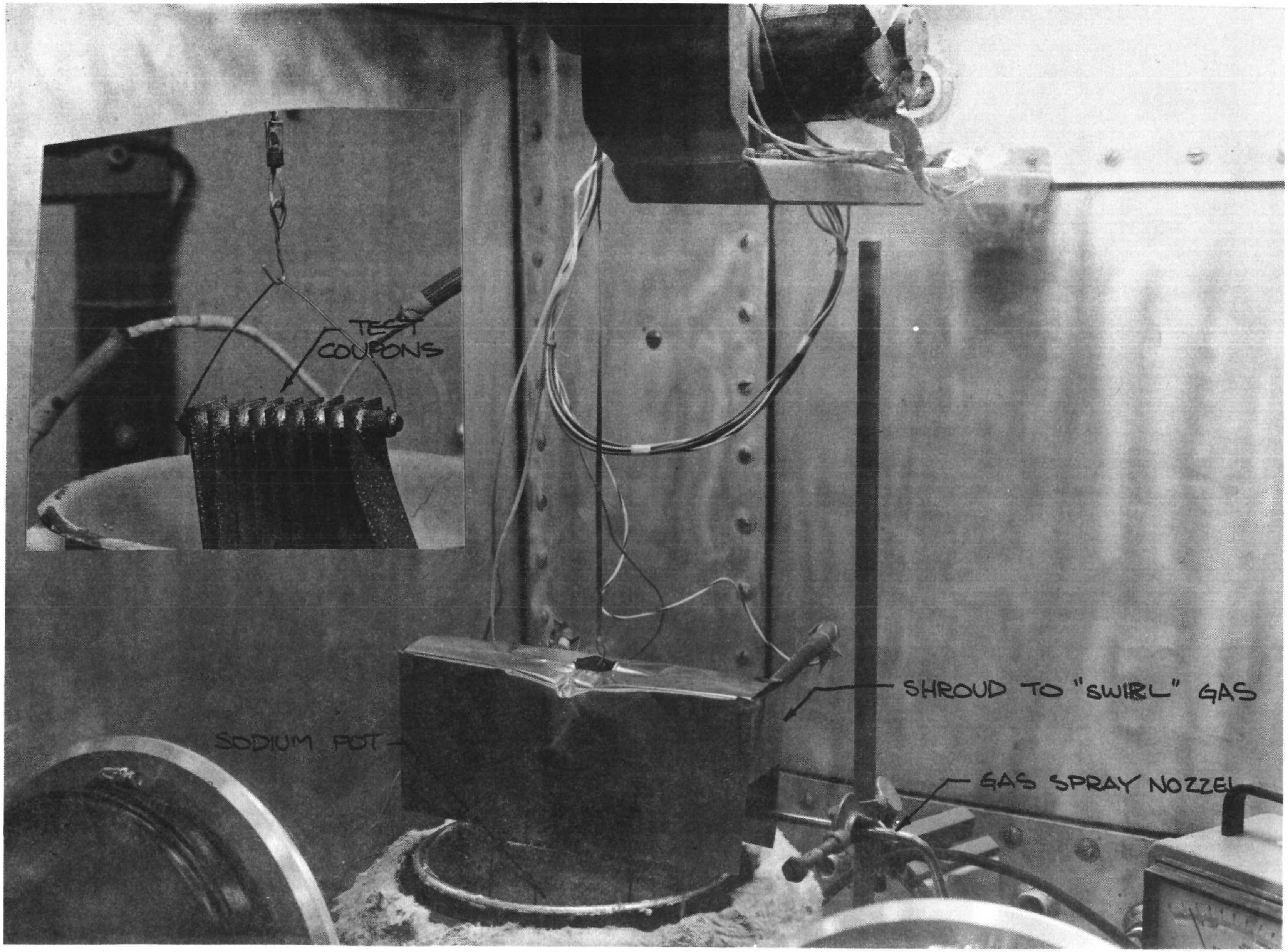
1. Tests 10-12

Tests 10-12 were run with argon plus the desired level of oxygen introduced directly into the glove box and with the gas recirculating purification system switched off. Tests 10-12 were run with $\sim$1, 10, and 5 ppm O_2, respectively, and all tests resulted in gettering of the O_2 by the static sodium pot and a subsequent build-up of an oxide layer on the sodium surface. As a consequence, the test coupons collected a substantial amount of "crud" on the surfaces which obscured the wetting evaluation. Figure 18 illustrates this buildup on the coupons and the oxide "crud" on the sodium surfaces for Test No. 11, with 10 ppm O_2 in the argon. The percent sodium coating given in Table IV for Tests 10-12 is therefore complicated by the prescence of the oxide.

The glove box system was modified such that, similar to the EVTM chain and tape chamber tests, the argon plus desired ppm level O_2 gas was introduced directly into into the region of the test coupons only during their 5 minute dwell in argon but with the glove box purification system turned on. This permitted the desired Ar/O_2 mix to be maintained at surfaces of the coupons and retained a clean sodium surface at the same time.

2. Test No. 13

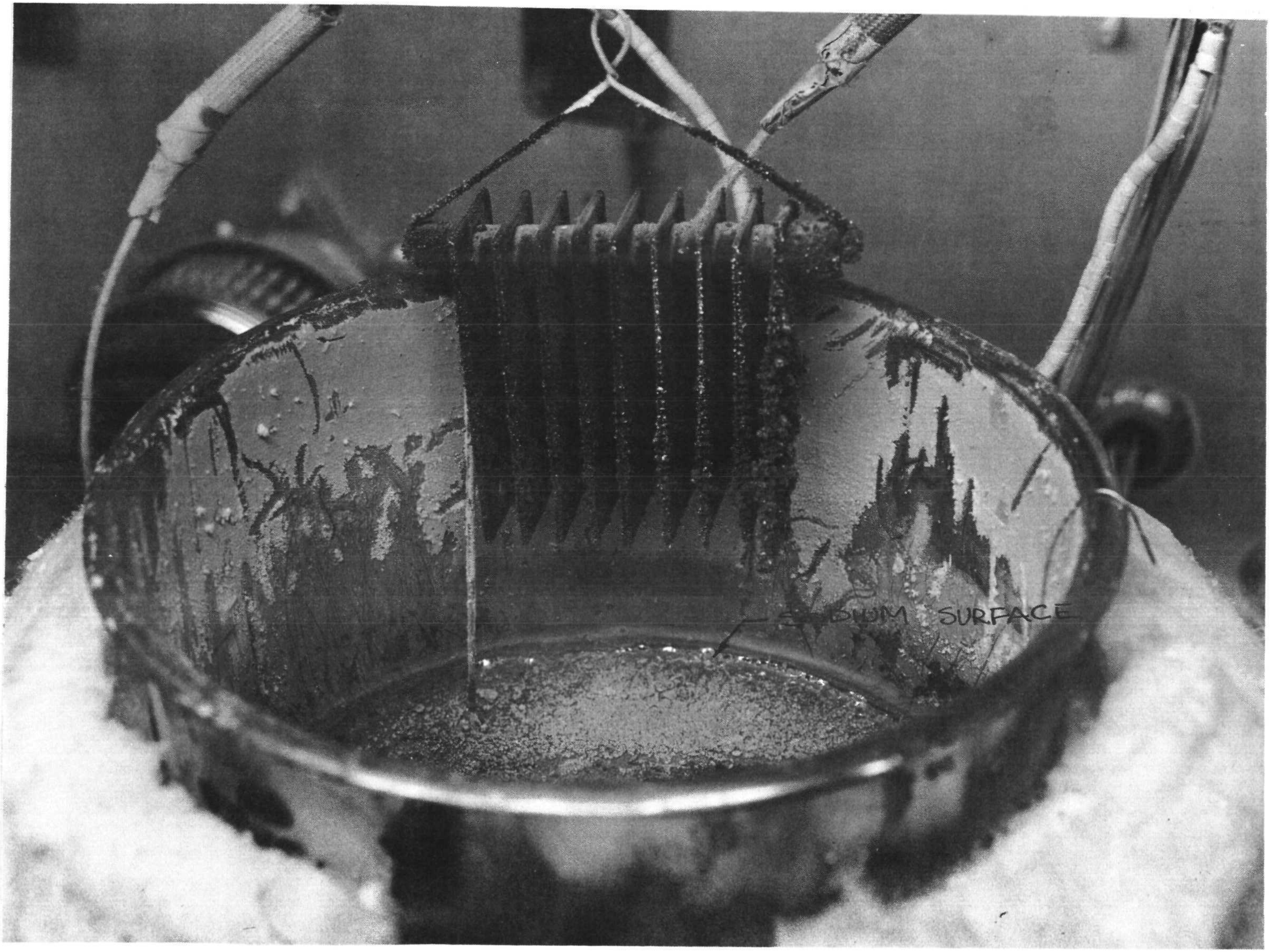
Test No. 13 was a rerun of Test No. 10 with $<$1 ppm O_2 and moisture in the argon gas atmosphere. The test was operated through two simulated lifetimes of operation (640 cycles) with $400^{\circ}F$ sodium. The tin plated coupon wet during the first immersion cycle and all other coupons showed less than 10% surface coverage by sodium droplets after the two years cycling. Results and test parameters are summarized in Tables III and IV.



Glove Box and Sodium Immersion Vessel

Figure 17.

9283- 11, 34



Test No. 11 - Coupons with Surface Oxide Buildup

Figure 18.

9283-18

3. Test No. 14

Test 14 duplicated Test 11 with $<$ 1 ppm moisture and 10 ppm O_2 in argon introduced at a flow rate of 40 sccm. This test was operated through two simulated life times and again the tin plated specimen wet immediately and no other coupons picked up any significant amount of sodium.

4. Test No. 15

Test 15 was run with $<$ 1 ppm moisture and 20 ppm O_2 in argon against a flow rate of 40 sccm. No coupon was observed to have more than 20% of its surfaces coated by the sodium. The tin plated coupon was omitted from the test matrix.

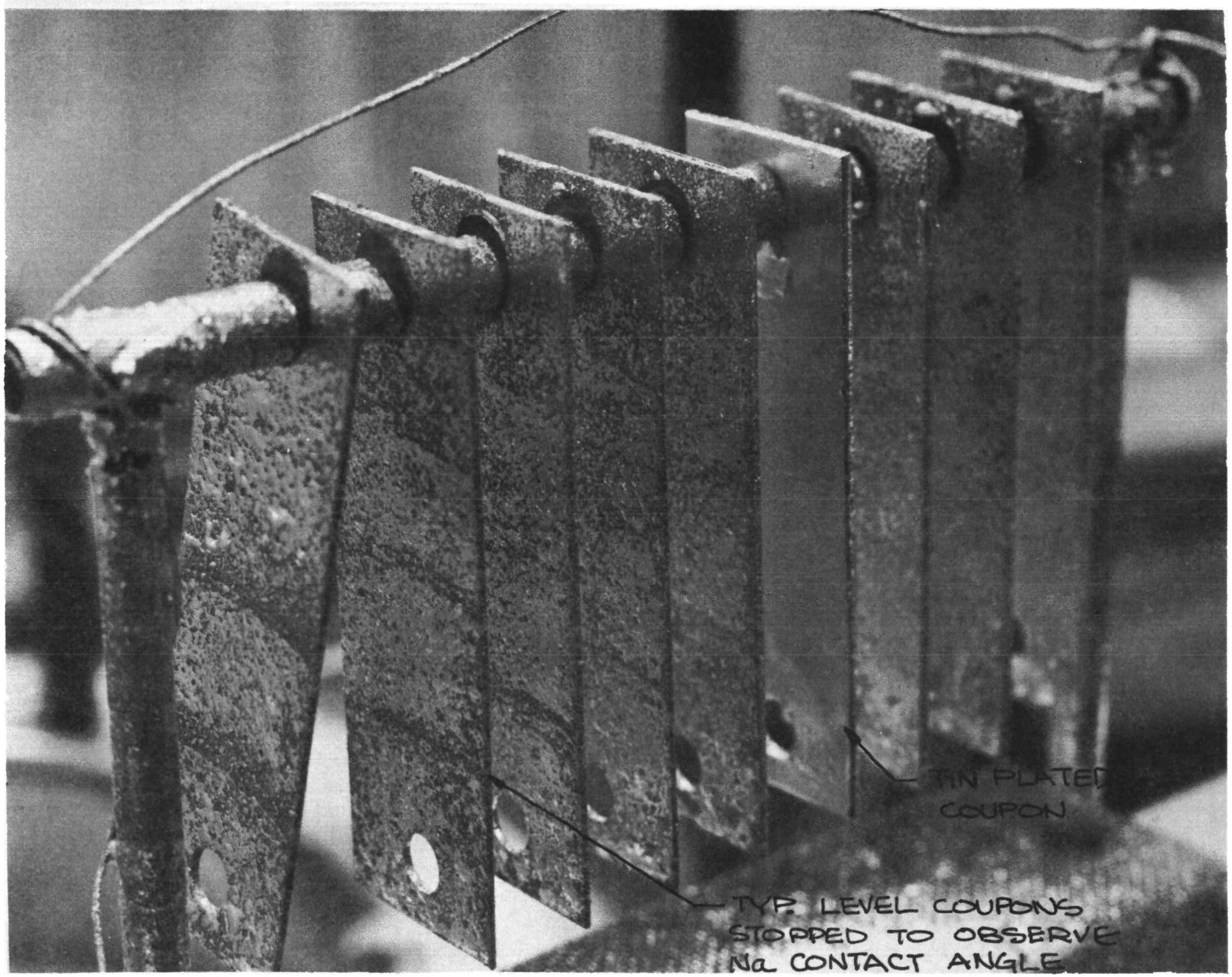
5. Test No. 16

Test No. 16 was run with $<$ 1 ppm moisture and 50 ppm O_2 in argon. The test was operated through two years of simulated operation with an argon + O_2 flow rate of 40 sccm (same as tests 13-15) and no indication of wetting was observed on any coupon (the tin plated coupon was omitted from the matrix). The two years simulated life was repeated at gas flow rates of 160 and 300 sccm. No increase in sodium adherence to the coupon surfaces were observed. The specimens were then subjected to a 200 hour continuous immersion in the $400^{\circ}F$ sodium with no change. As noted in Table IV, no coupon was judged to have more than 20% of its surfaces covered by sodium droplets.

6. Test No. 17

Test No. 17 was conducted with $<$ 1 ppm O_2 and $\sim$50 ppm moisture in argon with flow rate of $\sim$100 scm. The tin plated coupon wet during the initial immersion in sodium; and after $\sim$50 cycles, sodium droplets began adhering to the remaining coupons. After two simulated lifetimes (640 cycles), approximately 75% of the surfaces of all coupons were randomly coated with sodium.

While the tinned coupon had a smooth, shiny surface, all other coupons had a rough surface texture beneath the sodium layer consistant with previous tests conducted in the large environmental chamber. Figure 19 shows the coupons after 640 cycles and illustrates the difference between the tinned coupon (4th from the right) and the other coupons. The "lines"



Test No. 17 - Test Coupons after 640 Cycles at 400F

($<$1 ppm O_2, 50 ppm moisture)

Figure 19.

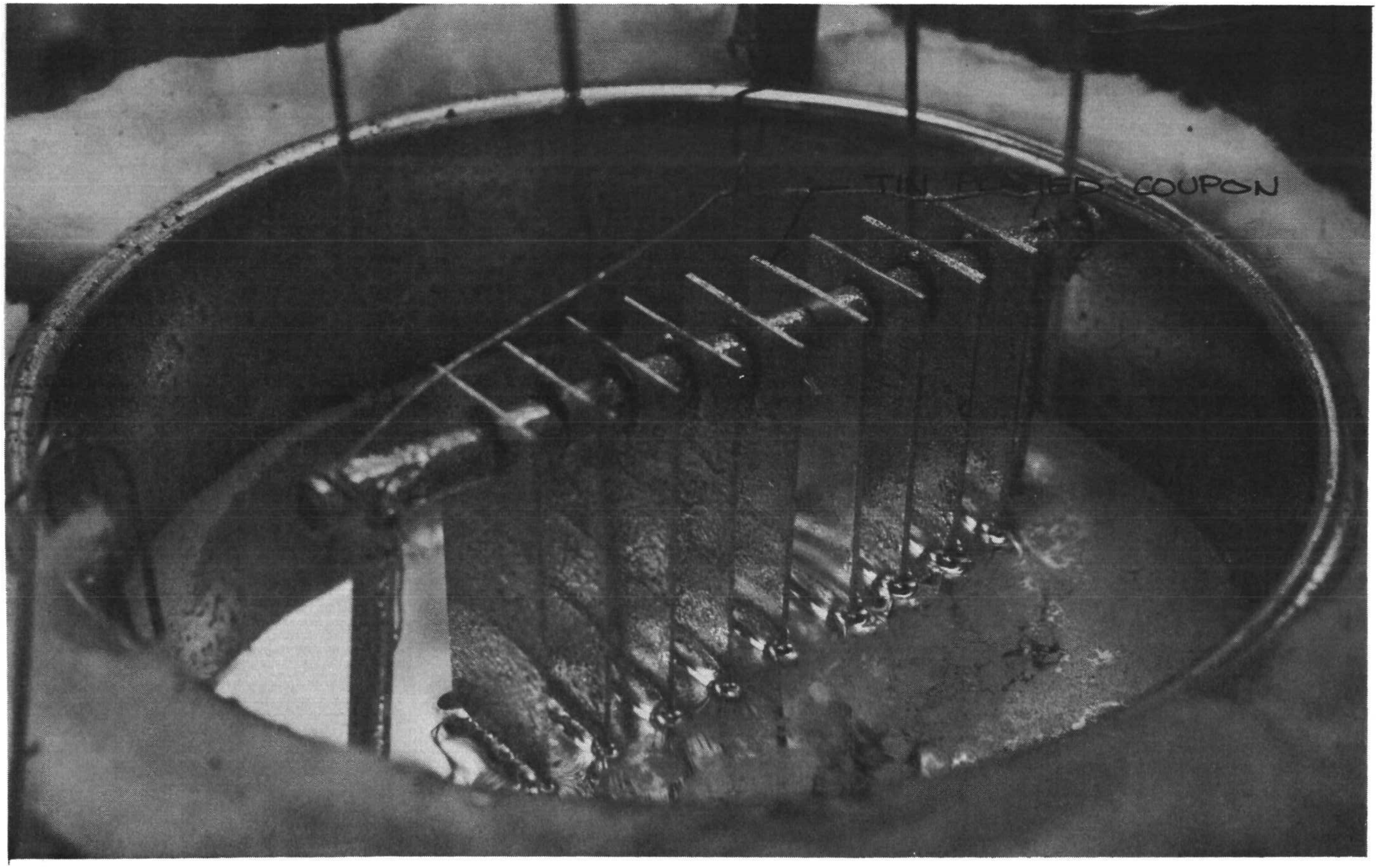
across the faces of the coupons are the result of periodically stopping the coupons mid-way into the sodium during cycling to observe the sodium contact angles. The contact angle between the sodium and the tin-plated coupon was significantly less than for the other coupons demonstrating a higher degree of "wetting". Figure 20 shows the coupons partially immersed in sodium and illustrates their relative contact angles. These coupons were subsequently immersed in the 400°F sodium for 600 hours with no increase in sodium wetting or decrease in the rough surface texture of the non-tinned coupons.

7. Test No. 18

A second set of test coupons was subjected to testing with $<$1 ppm O_2 and 25 ppm moisture in the argon cover gas. The tin plated coupon again wet during the initial immersion into sodium and with the accumulation of cycles sodium became more adherent to the remaining coupons. After approximately 100 cycles, the lifting mechanism failed in the up position and allowed the argon plus 25 ppm moisture to spray on the coupons for ~20 hours. This resulted in dewetting of the tin-plated coupon as the sodium film was oxidized. At the end of the two years' simulated operation (640 cycles) all coupons were approximately 50% coated, including the tin-plated coupon. The coupons were held in the box atmosphere for ~24 hours and showed a tendency to dewet. The percent of sodium coating noted in Table IV was measured after the coupons were held in the moisture containing gas and is illustrated in Figure 21. The coupons were then immersed in the 400°F sodium for 300 hours and showed a slight tendency to "rewet".

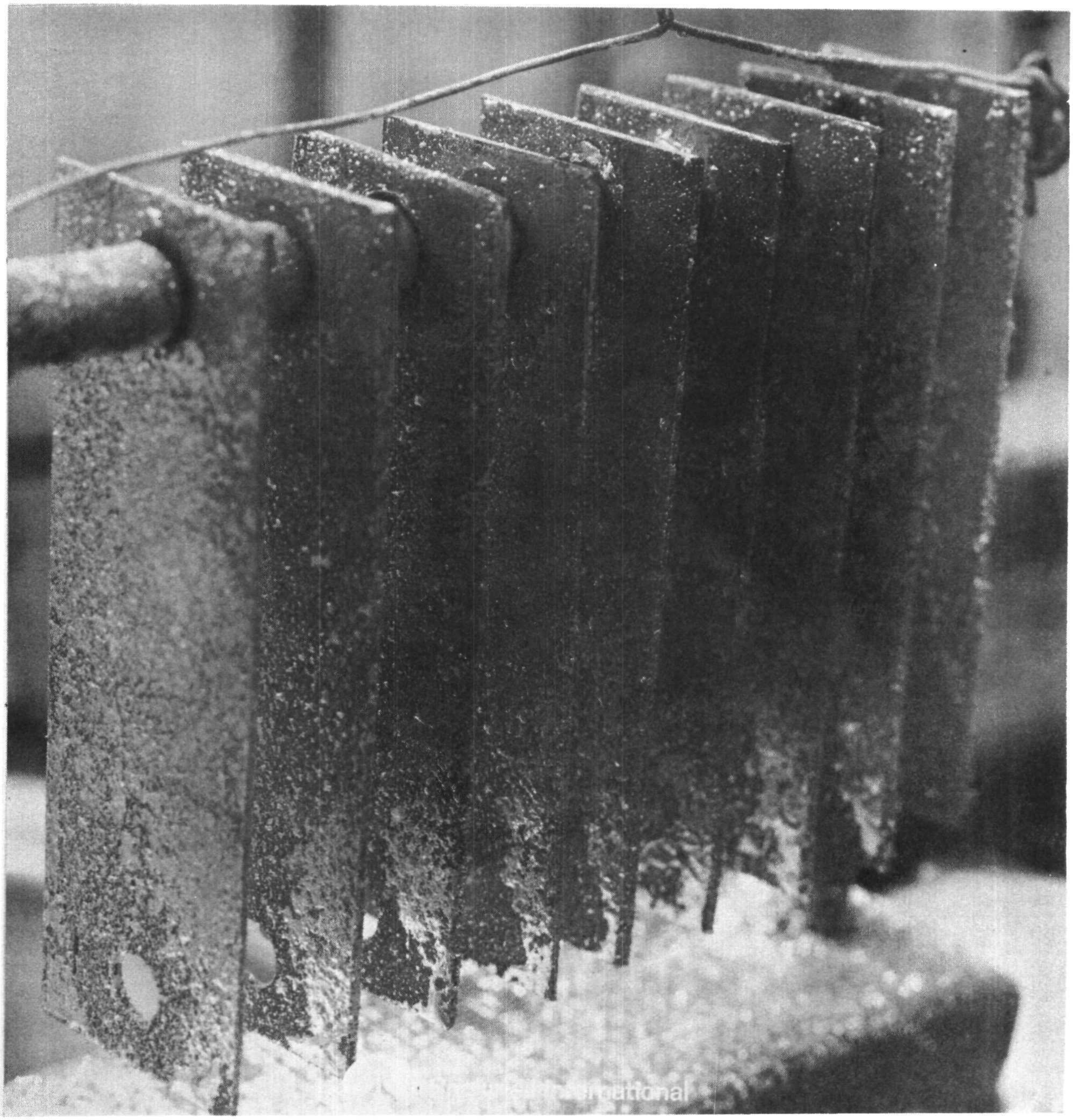
C. Sodium Carryover

The consequence of sodium adherence to the hoist chain is as the chain runs through the drive components, particularly the pocketwheel and cap assemblies, sodium is "carried over" and deposited in those components. Drive system overload and subsequent jamming in the EVTM chain and tape tests (ref. 1) was the prime impetus for these current tests. During the wetting tests, pick up of sodium by the chain and carryover into the drive mechanisms was monitored. Consistent with the previous tests, sodium was slowly accumulated on the back drive system pocketwheel and cap assembly and subsequently transferred to the upper section of the chain which was



Test No. 17 - Sodium Contact Angles

Figure 20.



Test No. 18 - Coupons after 640 Cycles in Sodium
and 20 hours in Argon + 50 ppm Moisture

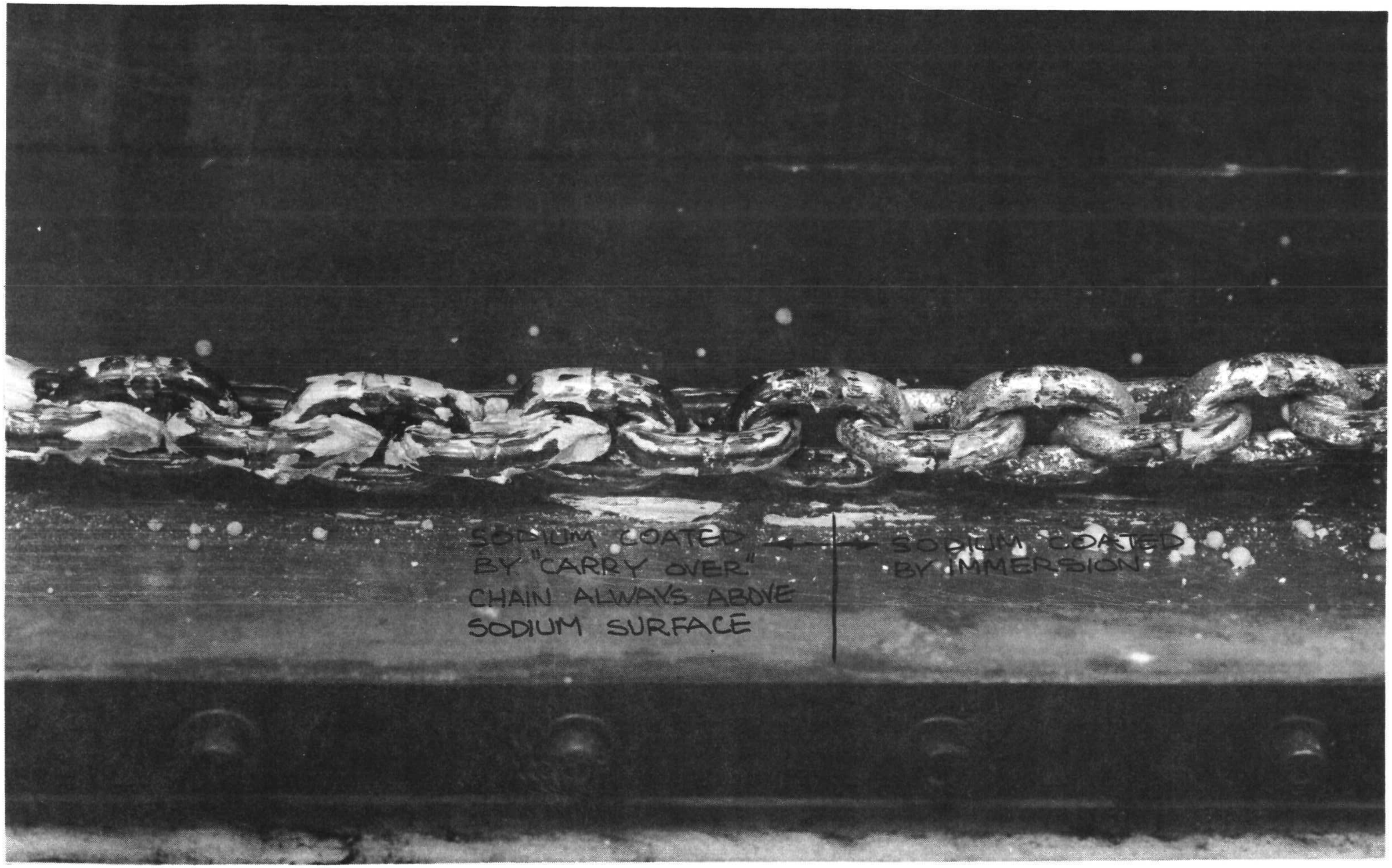
Figure 21.

never immersed in the sodium. The chain was removed at the end of the first four years of simulated testing for cleaning (after Test No. 4). Figure 22 shows the chain at the transition point between chain coated by immersion and chain (never immersed in the sodium) coated by "carryover." The difference in appearance is dramatic and illustrates the smooth film of sodium deposited by immersion as contrasted to the large globs of frozen sodium on the remaining chain.

Six ounces of sodium were removed from the chain and an additional four ounces from the drive system components, principally the rear cap. Figures 23 and 24 show the front and rear pocketwheel assemblies with the caps removed. The front pocketwheel and cap had very little sodium, while the rear cap is completely clogged with frozen sodium. These conditions are consistent with previous tests. It is hypothesized that the thin sodium film is adherent to the chain until frozen at which time it is scraped off by any contacting surfaces and due to the heat balance of the system, freezing of the sodium occurs after chain passes through the warmer front pocketwheel. It is therefore deposited on the rear pocketwheel and cap and smeared onto the cold chain links (those never immersed in sodium) as they pass through the drive assembly.

The chain jammed because of the sodium buildup on the rear pocket-wheel assembly during Test No. 8, after an additional 5 years of simulated operation. This caused an overload limit to trip and shut down the system. The system jammed under the same conditions during Test No. 9, with an accumulation of 2.2 years simulated operation and later in the same test after a total of 5.8 years testing.

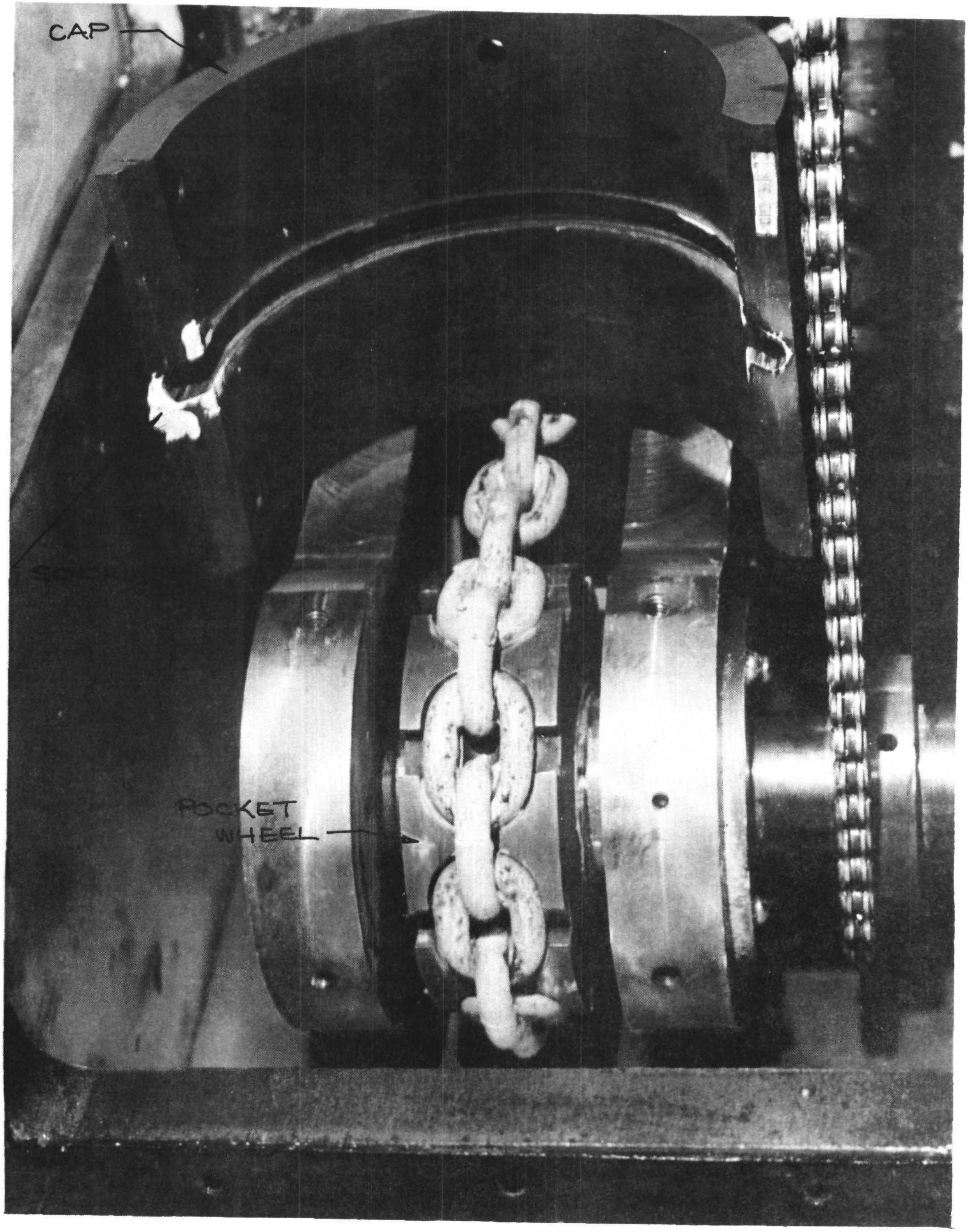
In each case, jamming and system shutdown were due to the accumulation of excessive sodium in the rear pocketwheel assembly. Such conditions are obviously detrimental and illustrate the necessity for removal of the excess sodium prior to chain disorientation and jamming. Two acceptable techniques would be a mechanical scraper or a hot gas lance (ref 5) to remove the sodium prior to entry into the hoist components.



Comparison of Sodium Adherence to Chain at Sodium
Immersion Carryover Interface

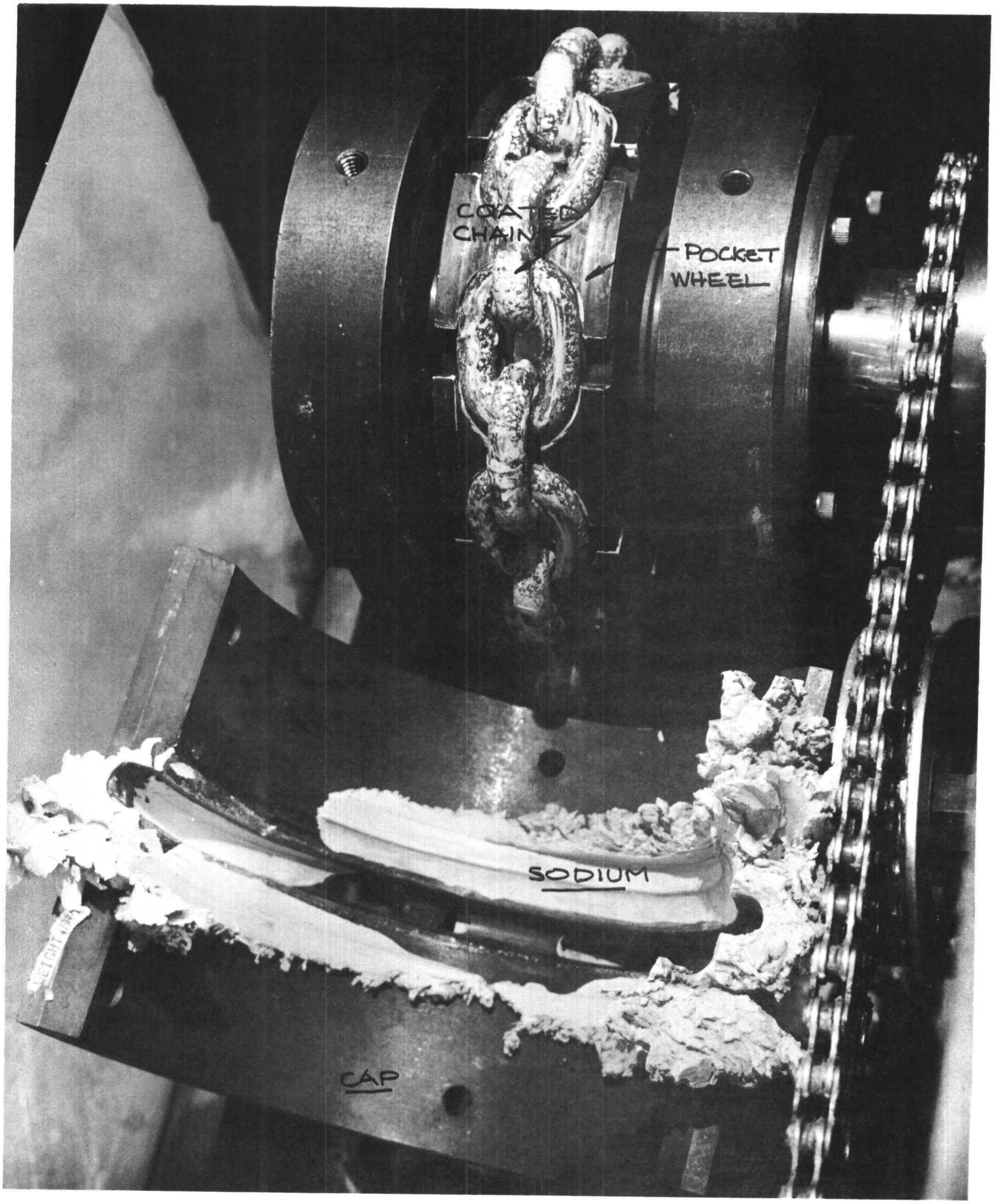
Figure 22.

9006-40845



Front Pocketwheel and Cap Assembly
(After Test No. 4)

Figure 23.



Rear Pocketwheel and Cap Assembly
(After Test No. 4)

Figure 24.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

Based on the results of these tests and similar activities (ref. 1 and 4), the following can be concluded:

1. Sodium wetting of the subject materials can not be achieved by long term immersion in 400°F sodium. This was verified by immersion tests of up to 2000 hours duration in sodium with oxygen levels of 4 to 13 ppm.
2. Wetting of the metal surfaces can be achieved almost instantly upon immersion in 400°F sodium if the surfaces are electroplated with a thin film ($\sim$.0005 in. or greater) of tin.
3. The above materials cycled in and out of 400°F sodium with a moisture containing cover gas (tests were conducted at 25 and 50 ppm moisture in argon) will have their surfaces coated with a near continuous layer of soidum. The rate of sodium deposition on the surfaces appears to be a function of moisture content in the gas and time at test. A threshold value was not established but it is expected to be $\sim$ 5 ppm. It is also expected that as the moisture level increases at the sodium surface, the process will be inhibited by excessive reaction products buildup.

It is postulated that the moisture in the gas resulted in a very light film of sodium reaction products, probably NaOH, being gradually deposited on the surfaces of the coupons as they passed in and out of the sodium. Additional sodium then adhered to this discontinuous film of reaction products giving the wetted appearance. The presence of the randomly deposited reaction products accounted for the rough surface texture and adhering globules of sodium. Upon cooling, the sodium coating had a tendency to "bead up" slightly but remain fully adherent to the coupon surfaces. These quasi-wetted surfaces would probably result in the transfer of more sodium to the drive system than if the surfaces were actually uniformly wetted. It is postulated that with time, in quantities of clean sodium, these reaction products would be dissolved, resulting in actual surface wetting.

4. The effect noted in Item 3 is not achieved when the materials are cycled in and out of sodium with a cover gas containing dry oxygen in the ppm range. Initial tests conducted in the EVTM environmental chamber which tended to support a relationship between sodium pickup and oxygen content were not substantiated in the controlled atmosphere of the glove box test series. As moisture content of the environmental chamber was measured midway between the coupon dwell position and the sodium surface, it is also possible that the moisture content had greater variation than indicated.

5. A method to limit excessive sodium buildup and transport on the hoist chain is required (mechanical scraper or hot gas lance).

B. RECOMMENDATIONS

Based on the above tests, the following recommendations are made:

1. An apparatus (mechanical scraper, hot gas lance) to prevent sodium carryover into the drive components should be designed, fabricated, and tested to demonstrate its effectiveness.

2. A laboratory scale test should be conducted to isolate the specific phenomenon and the related kinetics of moisture assisted quasi-wetting of materials. Classical sodium wetting is not discussed as feasible under these conditions in any literature studied. The complexity of the problem and the precise control required of the variables dictates a research approach.

VII. REFERENCES

1. N099TR413012, "Ex-Vessel Transfer Machine (EVTM) Grapple Chain/Tape Test Report (Rev. B)", T. J. Harmon and R. M. Oliva, 5-6-77.
2. N707TP830008, "Chain and Hoist Carryover - Test Plan", R. M. Oliva, 7-10-77
3. N707DTP830012, "Test Procedure - Chain Hoist Sodium Carryover Test," R. M. Oliva, 7-14-77
4. AI-DOE-13226, "Performance Tests of Sodium Dip Seals," T. T. Shimazaki, 2-28-78
5. TR-707-830-005, "Final Report, Hot Gas Lance Testing," M. Moriarty, 7-3-75.